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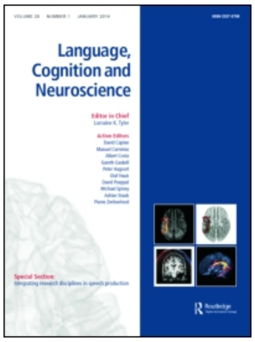

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Past tense formation in Williams syndrome

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It has been claimed that in the language systems of people with Williams syndrome (WS), syntax is intact but lexical memory is impaired. Evidence has come from past tense elicitation tasks with a small number of participants where individuals with WS are said to have a specific deficit in forming irregular past tenses. However, typically developing children also show poorer performance on irregulars than regulars in these tasks, and one of the central features of WS language development is that it is delayed. We compared the performance of 21 participants with WS on two past tense elicitation tasks with that of four typically developing control groups, at ages 6, 8, 10, and adult. When verbal mental age was controlled for, participants in the WS group displayed no selective deficit in irregular past tense performance. However, there was evidence for lower levels of generalisation to novel strings. This is consistent with the hypothesis that the WS language system is delayed because it has developed under different constraints, constraints that perhaps include atypical phonological representations. The

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results are discussed in relation to dual-mechanism and connectionist computational models of language development, and to the possible differential weight given to phonology versus semantics in WS development.

INTRODUCTION

Williams syndrome (WS) is a rare neurodevelopmental disorder occurring in approximately 1 in 20,000 live births (Morris, Demsey, Leonard, Dilts, & Blackburn, 1988). It is caused by a micro-deletion on one copy of chromosome 7 (Tassabehji et al., 1999) and results in specific physical, cognitive, and behavioural abnormalities (Karmiloff-Smith, 1998; Mervis, Morris, Bertrand & Robinson, 1999). The syndrome has been of particular interest to cognitive scientists because individuals with WS exhibit an uneven cognitive-linguistic profile together with mild to moderate mental retardation (Howlin, Davies, & Udwin, 1998; Mervis et al., 1999). Thus Udwin and Yule (1990) found that 54% of their sample of 43 WS participants had a full-scale intelligence quotient (IQ) of ≤ 50 and 42% had an IQ between 51–70. However, in general the full-scale IQ score in WS masks differences in specific cognitive abilities. The syndrome is often characterised as one where verbal abilities are superior to visuospatial abilities (Mervis et al., 1999), although in both areas performance is below that expected for chronological age. This pattern of uneven abilities may be one that emerges and increases over the course of development (Jarrold, Baddeley, & Hewes, 1998; Bellugi, Lichtenberger, Mills, Galaburda, & Korenberg, 1999). The uneven profile extends to other abilities. Thus while individuals with WS often perform within the normal range on standardised tests for face recognition (Bellugi, Wang, & Jernigan, 1994), and show relatively good performance on theory of mind tasks (Karmiloff-Smith, Klima, Bellugi, Grant, & Baron-Cohen, 1995), they exhibit difficulties in numerical cognition (Karmiloff-Smith et al., 1995), and in problem solving and planning (Bellugi, Marks, Bihrle, & Sabo, 1988).

The uneven cognitive profile found in WS has been of interest because it promises to offer the potential to identify developmental *fractionations* in the cognitive system. For example, given limitations in general cognition, the largely successful acquisition of language might be taken as evidence of the developmental independence of language from cognition (see Mervis & Bertrand, 1997; Rossen, Bihrle, Klima, Bellugi, & Jones, 1996). A similar argument might be made for the developmental independence of face recognition from spatial cognition. Given the standard assumption that the adult cognitive system has a modular structure and that WS has a genetic origin, there is an additional temptation to link dissociations in the cognitive abilities of adults with WS with damage to or sparing of innate cognitive modules. This approach attempts to extend the logic of adult neuropsychology in which patterns of adult brain damage are taken to reveal (under some circumstances) the functional modules comprising the cognitive system. When extended to developmental disorders that have a genetic basis, the implication is that deficits in the endstate behaviour of individuals will reveal the *innate* modular structure of the cognitive system (see e.g., Baron-Cohen, 1998; Temple, 1997). In this paper we will seek to question whether the adult brain damage model is indeed appropriate for characterising behavioural deficits found in developmental disorders. To do so, we will examine a specific example, that of the acquisition of past tense formation in Williams syndrome.

WS and SLI: a double dissociation of innate mechanisms?

Williams syndrome has been used to support the presence of innate structure in the normal language system. This innate structure supposes the existence of two sorts of mechanism, a computational, syntactic, rule-based mechanism responsible for learning the abstract rules of grammar, and an associative memory system responsible for learning information about individual words (Pinker, 1991, 1994, 1999). We will refer to this as the dual-mechanism account, by which we specifically mean a model with one rule-based mechanism and one associative mechanism. (It is of course possible to have dual-mechanism accounts where both mechanisms are rule-based or both are associative. Debates about the quantity of mechanisms are orthogonal to those about the nature of those mechanisms.) Pinker (1991) proposed that Specific Language Impairment (SLI) and Williams syndrome together provide a developmental double dissociation between these two language mechanisms. SLI is a developmental disorder in which impairments are found in language in the absence of any apparent cognitive, social, or neurological deficits. In addition, there is a genetic component to this disorder (Bishop, North, & Donlan, 1995). Referring to evidence from Gopnik and Crago (1991), Pinker proposed that people with SLI have an impairment to the syntactic, rule-based device, but that their ability to memorise words is intact. Citing evidence from Bellugi, Bihrle, Jernigan, Trauner, and Doherty (1990), he further proposed that in Williams syndrome, there is a “selective sparing of syntax, and grammatical abilities are close to normal in controlled testing” (p. 479), but that there is an impairment to the associative memory mechanism such that individuals “retrieve words in a deviant fashion” (ibid.). In short, we have the claim that the two mechanisms can be dissociated because they can independently fail in two distinct developmental disorders, forming, as Pinker describes it, a “genetic double dissociation” (1999, p. 262).

Much of the behavioural evidence behind this proposal comes from performance on forming the English past tense. The English past tense is characterised by a rule in which the past tense of a verb is formed by adding the suffix *-ed* to the verb stem (e.g., talk-talked). However, there is also a minority of verbs which form their past tense in different ways (e.g., go-went, think-thought, hit-hit). These irregular or exception verbs often fall into clusters sharing a family resemblance (e.g., sleep-slept, creep-crept, leap-leapt). The English past tense is important for Pinker's dual-mechanism theory, since performance on the regular and irregular past tense formations are taken to directly index, respectively, the functioning of the rule-based and associative mechanisms. Pinker's claims about SLI and WS then translate into the following empirical predictions: (1) we should expect individuals with SLI to show a selective deficit in forming regular past tenses but not irregular past tenses; (2) we should expect individuals with WS to show a selective deficit in forming irregular past tenses but not regular past tenses. Recent work has sought to address these claims in detail.

SLI: deficit on regulars but not irregulars?

Van der Lely and Ullman (this issue) have examined English past tense formation in a sample of children with "grammatical" SLI. SLI is a heterogeneous disorder (Aram, Morris, & Hall, 1993) which may have a number of underlying causes. Van der Lely and Stollwerck (e.g., van der Lely, 1997; van der Lely & Stollwerck, 1996) have identified a subgroup of children with SLI based on behavioural measures, such that their predominant deficit is restricted to grammatical abilities. Van der Lely claims that, at least for this subgroup, their disorder can be characterised as a "primary deficit in the computational syntactic (grammatical) system" (van der Lely, 1998). Van der Lely and Ullman found that in a past tense elicitation task, the children with SLI predominantly responded by reproducing the stem without marking it, accounting for approximately 65% of all responses. In terms of correct performance, the children with SLI showed no advantage of regular over irregular verbs which, compared to controls, represented a greater deficit on regulars than irregulars. Lastly, they found frequency effects in the performance of the SLI group on regular verbs, an affect normally confined to irregular verbs. On the assumption that Pinker's dual-mechanism model is correct, van der Lely and Ullman took these results as supporting the view that in grammatical SLI, the rule-based mechanism is impaired but the associative memory is intact. Although the children with SLI provided some correct regular past tense items, these were taken as reflecting compensatory activity of the associative memory. Frequency effects are taken as a hallmark of such an associative system. Van der Lely and Ullman thus interpreted the frequency effects found in regular past tense formation as an indication that, in the absence of a rule-based mechanism, all past tenses were being treated as exceptions (see also Ullman & Gopnik, 1999).

Williams syndrome: deficit on irregulars but not regulars?

Clahsen and Almazan (1998) recently examined the performance of four children with WS (aged 11;2 to 15;4) on a range of grammatical tasks. These included an analysis of expressive language in story telling, a test of comprehension of active and passive sentences, a test of the comprehension of sentences using syntactic binding in referential dependencies between anaphoric elements, a test of inflection morphology (English past tense formation), and a test of derivational morphology (past tense formation for normal and denominal irregular verbs). The analysis of expressive language showed that the performance of the WS group was appropriate for their mental age (as measured by their overall scores on the Wechsler Intelligence Scale for Children-III; Wechsler, 1992), and that their language comprised complex syntactic structures and grammatical morphemes that were almost always correct. Performance of participants with WS on the particular tests used for passives and syntactic binding was at ceiling.

Clahsen and Almazan used the same past tense elicitation procedure as van der Lely and Ullman so the results are directly comparable. Their results pointed to a selective deficit in irregular past tense formation in two individuals with WS with mental ages (MA) of 5 years and two individuals with WS with MA of 7 years compared to MA-matched control groups. They concluded that the individuals with WS had an impaired associative memory mechanism, citing as evidence the fact these participants *irregularised* novel verbs which rhymed with existing irregular verbs (e.g., *crive-crove*, *drive-drove*) at a much lower rate than their controls. Thus participants with WS "seemed to be impaired (relative to controls) in associating phonological patterns of novel verbs to corresponding strings of existing irregular verbs" (p. 193). On the assumption that Pinker's dual-mechanism model is correct, Clahsen and Almazan concluded that in Williams syndrome, the "computational system for language is selectively spared yielding excellent performance on syntactic tasks and on regular inflection, whereas the lexical system and/or its access mechanisms required for irregular inflection are impaired" (ibid.). Their results on inflectional morphology in WS are in line with previous unpublished data for six participants with WS presented by Bromberg, Ullman, Coppola, Marcus, Kelley, and Levin (1994).

Problems with existing WS past tense data

There are two serious problems with the current data on inflection morphology in Williams syndrome. Firstly, *typically* developing children usually show poorer performance on irregular verbs than regular verbs (with the exception of the very early stages of language development where vocabulary size is small) (Bybee and Slobin, 1982; see also van der Lely & Ullman, this issue). One of the most salient characteristics of language development in Williams syndrome is that it is delayed (Mervis et al., 1999; Singer Harris, Bellugi, Bates, Jones, & Rossen, 1997; Thal, Bates, & Bellugi, 1989). Therefore, to show a selective deficit in irregular past tense formation in individuals with WS, it is not enough to demonstrate that irregular past tense formation is poorer than regular past tense formation. Rather, it must be shown that their level of past tense formation is poorer than we would expect *given their level of language development.* In the unpublished data of Bromberg et al. (1994), no such comparison is possible since participants with WS were only roughly matched to normal controls. While the comparison is possible for the Clahsen and Almazan data, their study only comprised four individuals with WS, and even for these, the data appear fairly noisy. For example, for irregular verbs, the two individuals with MA of 5 scored 14% correct on irregular verbs compared to the 57% correct scored by the two individuals with MA of 7. And when performance on irregulars was re-tested as a control condition in the derivational morphology task, the MA-5 individuals now scored 44% correct. On the evidence of this study alone, one cannot be confident that the apparent deficit on irregular verbs in the WS group is any more than a consequence of delayed language development.

Secondly, Clahsen and Almazan note a marked difference between the WS and control groups in how willing they were to extend patterns of irregular past tense formation to novel items (e.g., *crive-crove*). Levels of irregularisation were much lower in the WS group and they took this as revealing an impairment to lexical associative memory. However, the control data Clahsen and Almazan used in this comparison look very different to those collected by van der Lely and Ullman (2000) on exactly the same task. Clahsen and Almazan's two control groups irregularised novel rhymes at rates of 68% and 75%. Van der Lely and Ullman's groups, of a similar age, irregularised novel rhymes at levels of 10%, 9%, and 10%. These latter levels are much closer to the rates that Clahsen and Almazan reported for their WS group. Thus the apparent deficit shown by the WS group would seem to depend crucially on the true level of novel irregularisation in the normal population at an equivalent level of language development.

In our study, we set out to rectify these problems in order to establish whether the performance of individuals with WS in irregular past tense formation is indeed reliably poorer than would be expected for their level of language development. We did this in three ways. Firstly, we examined a much larger sample of participants with WS than the Clahsen and Almazan study. Secondly, we sought to build a normal developmental profile of performance on this particular task against which we could compare the performance of the WS group. To do so, we tested four groups of control participants, aged 6, 8, 10, and adult. Thirdly, we employed an additional past tense elicitation task to explore whether any features of the Clahsen and Almazan results were due to particular features of the task they used.

The second elicitation task was developed for use with patients with brain damage by Lorraine Tyler and William Marslen-Wilson. This task does not require participants to repeat sentences and instead provides them with the initial sound of the past tense form. Consequently, it may be seen as having a lower memory load. In addition, it employed a set of regular and irregular verbs three times as large as that used in the Clahsen and Almazan (1998) study. This larger set of verbs allowed us to explore underlying factors in the elicitation task, such as the role of verb frequency and verb imageability in past tense formation. We have already seen that frequency effects have been taken as a hallmark of lexical associative processing. Evidence of effects of imageability, a semantic dimension differing across verbs, could also be taken to implicate lexical memory in the operation of the grammatical process of past tense formation.

Two contrasting hypotheses were tested in the current study. The first represents the Pinker/Clahsen and Almazan position: Individuals with Williams syndrome show a specific deficit in irregular past tense formation. Thus if one controls for language ability, one should expect performance on regulars to be the same for the WS and control groups. On the other hand, one should expect performance on irregular verbs to be lower for the WS group than the control group. With novel items, one should expect performance on regularising novel words which do not rhyme with any existing irregular verb to be the same as controls (e.g., *stoff-stoffed*). On the other hand, one should expect performance on irregular rhyming novel verbs to be different from controls. Perhaps the WS group might show less irregularisation (e.g., *crive-crove*), in keeping with the hypothesis of an impaired associative mechanism, or more regularisation, in keeping with the hypothesis of a preserved rule-based mechanism (e.g., *crive-crived*).

The alternative hypothesis suggests that poor performance on irregular past tense formation in WS is a marker of their delayed language development. If one controls for level of language ability, performance on regulars and irregulars should be the same in participants with WS and controls. One should find a similar pattern in performance on novel items.

METHOD

Participants were tested on two tasks, both of which were designed to elicit past tense verb forms but which imposed somewhat different demands on memory. Task 1 was adapted from Ullman (1993), Ullman et al. (1997), and Clahsen and Almazan (1998). Task 2 was developed by Tyler and Marslen-Wilson.

Participants

Twenty-one children and adults with WS, 12 male and 9 female, were recruited through the Williams Syndrome Foundation UK to take part in this and other studies. Mean chronological age was 22;8 (range 10;11–53;3). Mean General Cognitive Ability (GCA; IQ equivalent as assessed by the British Abilities Scale II) was 45, (range 39 (floor)–73).

Three groups of typically developing children were also tested, with five boys and five girls in each group. Their mean ages were as follows: 5–6-year-olds = 6;0 (range 5;5–6;40), 7–8-year-olds = 8;1 (range 7;8–8;5), 9–10-year-olds = 9;10 (range 9;6–10;6). These children attended a North London primary school. A group of 16 normal adult controls were recruited by means of notices placed at Great Ormond Street Hospital and in a local community centre. Ten males and six females took part in the study, with a mean age of 30;5 (range 17;3–45;0). Participants in all groups were drawn from a range of socio-economic classes.

Materials

Task 1. Fifty-six sentence pairs were constructed according to the form illustrated in the following two examples:

(1) *Every day I slam a door*
Just like every day, yesterday I .... a door
(2) *Every day I swim in the pool*
Just like every day, yesterday I .... in the pool

The verbs in these sentences were those used by Clahsen and Almazan (1998). Existing regular and irregular verbs were matched for frequency and familiarity (see van der Lely & Ullman, this issue). The stimulus set is shown in Table 1. It included 16 existing regular verbs, 14 existing irregular verbs, 12 novel verbs with stems which did not rhyme with any existing irregular verbs, and 14 novel verbs which rhymed with existing irregulars.

TABLE 1
Stimulus sets for the two past tense elicitation tasks

Task 1				*Task 2*			
Regular verbs	*Irregular verbs*	*Non-rhyme novel items*	*Irregular-rhyme novel items**	*Regular verbs*		*Irregular verbs*	
scowl	swim	spuff	strink (strunk)	kick	laugh	stick	shrink
tug	dig	dotch	frink (frunk)	croak	help	creep	sing
flush	swing	stoff	strise (strose)	climb	mix	mislead	draw
mar	wring	cug	crive (crove)	stay	shave	shake	learn
chop	bend	trab	shrell (shrelt)	balance	agree	deal	keep
flap	bite	crog	vurn (vurnt)	dance	drag	begin	meet
stalk	feed	vask	steeze (stoze)	trim	leak	bleed	come
scour	make	brop	shrim (shram)	chase	stop	choose	grow
slam	give	satch	cleed (cled)	graze	call	leap	ring
cross	think	grush	sheel (shelt)	share	raise	cling	dream
rush	stand	plam	blide (blid)	walk	move	sting	shine
rob	keep	scur	prend (prent)	fix	shove	hang	lose
drop	drive		shreep (shrept)	bless	save	weep	drink
look	send		drite (drote)			feed	
stir							
soar							

* possible irregularisation shown in parentheses.

In order to optimise the enunciation and audibility of past tense endings produced by participants, each verb was followed by a noun phrase or prepositional phrase whose first word began with a vowel (the past tense verb ending in a sentence such as *Yesterday I robbed a bank*, whose verb is followed by a word starting with a vowel, is often more full articulated and/or more audible than in a sentence such as *Yesterday I robbed the bank*, where a consonant follows the verb ending).

Fourteen pairs of practice sentences were also constructed, using the same format as the test sentences. These incorporated six irregular verbs, four regular verbs, and four novel verbs with stems which did not rhyme with any existing irregular verbs.

Task 2. In this task, participants received the initial phoneme of the past tense form as a cue. The stimuli consisted of 53 sentences, each paired with an incomplete sentence, for example:

(1) *The bull sometimes kicks.*
Yesterday, it k..........

(2) *Maggie always hangs the pictures.*
Last time, she h..........

Twenty-six regular verbs and 27 irregular verbs were used in the test sentences. These were matched for frequency and imageability. Two practice sentences were constructed using irregular verbs.

Standardised tests

The participants with WS were also tested on the British Picture Vocabulary Scale (BPVS; Dunn et al., 1982) and seven subtests of the British Abilities Scales II (BAS–II; Elliott, 1996), namely Recall of Designs, Pattern Construction, Word Definitions, Verbal Similarities, Matrices, Quantitative Reasoning and Recall of Digits Forward. Table 2 shows the individual participant scores for chronological age, BPVS, General Cognitive Ability (GCA) from BAS (a composite score based on

TABLE 2
Ages and standardised test results of participants with Williams syndrome

Subject	*Chronological Age*	*BAS General Cognitive Ability*	*BPVS test age*	*Verbal MA (BAS subtests)*	*Spatial MA (BAS subtests)*	*Non-verbal MA (BAS subtests)*
		(Floor 39)	*(Floor 1;8, ceiling 19;6)*	*(Floor 5;0, ceiling 18;0)*	*(Floor 5;0, ceiling 18;0)*	*(Floor 5;0, ceiling 18;0)*
1*	10;11	44	5;2	5;10	5;0	5;4
2	11;1	48	6;8	6;9	5;0	6;2
3	11;3	46	9;3	7;11	5;10	8;2
4	11;5	44	5;3	5;7	5;0	6;2
5	11;7	47	9;0	7;0	5;1	7;0
6*	12;6	39	5;2	5;0	5;0	5;0
7	12;9	54	8;1	8;6	5;4	7;3
8	13;11	46	5;5	7;3	5;1	7;4
9	14;4	41	8;0	7;9	5;4	6;4
10	15;6	39	8;1	6;9	5;4	5;6
11	18;7	40	8;9	6;6	6;9	6;9
12*	19;3	39	5;0	5;0	5;0	5;0
13	20;10	39	8;4	6;10	5;0	5;2
14	21;8	39	7;1	6;12	5;0	5;0
15	27;6	39	8;8	6;10	5;6	5;0
16	30;3	39	15;4	7;4	5;2	6;7
17	30;8	51	15;7	13;9	6;7	7;2
18	34;9	39	7;10	6;4	5;0	5;0
19	42;9	73	19;6	16;5	8;9	10;6
20	50;11	50	13;11	13;0	5;4	7;11
21	53;3	39	14;3	9;0	5;2	6;1
Mean	22;8	44	9;7	7;11	6;5	5;6

* Starred participants were unable to complete the past tense elicitation tasks.
BAS, British Abilities Scale; BPVS, British Picture Vocabulary Scale; MA, mental age

performance on the first six subtests listed above), as well as subscores for verbal mental age, spatial mental age, and non-verbal mental age derived from the BAS (Verbal = mean of Word Definitions and Verbal Similarities; spatial = mean of Recall of Designs and Pattern Construction; non-verbal = mean of Matrices, Quantitative Reasoning and Recall of Digits Forward). The three starred participants in Table 2 were unable to complete the elicitation tasks. The verbal subscore test age was significantly higher than both non-verbal and spatial test ages (7;11 vs. 6;5, $t = 3.42$, df = 20, $p = .003$; 7;11 vs. 5;6, $t = 4.75$, df = 20, $p < .001$). Finally, non-verbal test age was significantly higher than spatial (6;5 vs. 5;6, $t = 4.48$, df = 20, $p < .001$). Thus our sample of participants with WS reflects the usual pattern, with verbal abilities superior to visuospatial abilities.

Design and procedure

The participants with WS and adult controls were tested at the Neurocognitive Development Unit in London. One experimenter introduced the tasks and presented the stimuli while two experimenters noted the participants' responses. All sessions were audio tape-recorded using a DAT recorder. The child controls were seen by two experimenters at their school. One experimenter administered the task while the other wrote down the responses. Since one of the aims of the study was to replicate the results obtained by Clahsen and Almazan (1998), their task was always given first, followed by Task 2.

Task 1 was presented as a game called "Fill in the missing word". The experimenter said: "I'm going to say something like *Every day I eat an orange* and you have to repeat that—try that now." Once the participant had successfully repeated the sentence the experimenter went on: "Then I'll say something like *Just like every day, yesterday I .... an orange* and you have to finish the sentence to fit in with what happened yesterday. So after I say, *Just like every day, yesterday I .... an orange* you might say *Yesterday I* (brief pause in case the participant was able to complete the sentence spontaneously) *I ATE an orange*." A second practice trial was presented in the same way. Participants were then told that they might hear some words they didn't know and they should simply say what they thought sounded right. The experimenter continued with practice trials until seven had been attempted, and then presented the test sentences, unless the participant did not seem to understand the task in which case further practice sentences were provided.

The test trials were presented in two blocks of 28, usually with a brief pause between the two blocks. The second block was preceded by further practice trials if the experimenter deemed it helpful. A single pseudo-random order of sentence pairs was used for each block, with numbers of exemplars of each of the four sentence types distributed equally across the two blocks.

The second task was then introduced as a game called ‘‘Finish the word I started’’. One experimenter said: ‘‘I’m going to say a sentence, and then I’ll start another one and stop in the middle. Your job is to finish off the word that I’ve started.’’ Participants were given only the first phoneme of the past tense form as a recall cue. The two practice sentences were presented, followed by the test sentences in a single pseudo-random order.

After the session, the two experimenters who had written down the participant’s responses checked for agreement. Any disagreement was resolved by listening to the audio tape.

The BPVS and BAS-II were administered to all the participants with WS by a single experimenter, either during the same visit or on a separate but closely dated occasion.

RESULTS

Three of the participants with Williams syndrome were unable to complete the past tense elicitation tasks. In two cases (participants 1 and 6), this appeared to be due to an inability to understand the metacognitive demands of the task. In at least one case (participant 12), the level of language as a whole was very poor. In this participant’s spontaneous production, there was little evidence of any inflections, as well as poor syntax, missing articles and prepositions, and a large proportion of incomplete sentences. Participants 6 and 12 were at floor on all subtests of the BAS–II.

Responses for the remaining 18 participants with WS and the 46 control participants were coded according to eight categories. These were as follows (illustrated using the examples of *leak* and *creep*): regularised (leaked, creeped), irregularised (lekt, crept), unmarked (leak, creep), substitution of other real word (dripped, walked), blend (lekted, crepted), third person singular (leaks, creeps), no response, and other. All irregular verbs formed their past tense by an internal vowel change and/or the change of a final consonant. For both tasks, an irregularised response was defined according to the same template. Nonsense strings that did not fall under this definition were classed as ‘‘other’’.

Because some of these response categories were sparsely filled, and for reasons of space, four of the categories (blend, 3rd person, no response, other) have been pooled together in the results shown in Table 3.

Within the WS group, there was, unsurprisingly, a fair degree of between-participant variability. By comparison, the 6-year-old group showed an equivalent level of variability, but the other three control

TABLE 3
Percentages of elicited past tense forms (bold figures show correct response for existing verbs)

		Response (%)				
Task	*Verb type*	*WS*	*6*	*8*	*10*	*Adult*
Task 1	Existing regular					
	Regular	**76.7**	**73.8**	**94.4**	**97.5**	**98.0**
	Irregular	0.0	0.6	0.0	0.0	0.0
	Unmarked	17.0	18.8	2.5	0.6	1.6
	Substitution	3.5	3.1	1.3	0.0	0.0
	Other	2.8	3.8	1.9	1.9	0.4
	Existing irregular					
	Regular	18.3	23.6	28.6	20.7	3.1
	Irregular	**52.0**	**42.1**	**68.6**	**76.4**	**95.5**
	Unmarked	26.2	32.9	2.9	1.4	0.9
	Substitution	2.0	0.7	0.0	0.0	0.0
	Other	1.6	0.7	0.0	1.4	0.4
Task 2	Existing regular					
	Regular	**82.5**	**80.4**	**99.6**	**97.7**	**98.6**
	Irregular	1.7	1.2	0.0	1.2	1.0
	Unmarked	5.8	5.8	0.0	0.0	0.2
	Substitution	2.4	2.3	0.0	0.4	0.0
	Other	7.7	10.4	0.4	0.8	0.0
	Existing irregular					
	Regular	26.7	31.1	20.4	13.3	2.8
	Irregular	**54.3**	**45.2**	**77.0**	**84.4**	**97.2**
	Unmarked	5.3	5.6	0.0	0.0	0.0
	Substitution	3.5	1.5	0.0	0.4	0.0
	Other	10.1	16.7	2.6	1.9	0.0
Task 1	Novel non-rhyme					
	Regular	57.4	60.0	93.3	97.5	92.7
	Irregular	0.5	0.0	0.0	0.0	1.0
	Unmarked	22.7	12.5	5.0	1.7	3.1
	Substitution	9.3	15.8	0.0	0.0	0.0
	Other	10.2	11.7	1.7	0.8	3.1
	Novel rhyme					
	Regular	40.1	44.3	75.7	81.4	51.3
	Irregular	4.8	6.4	6.4	10.0	34.4
	Unmarked	32.1	30.0	12.9	5.0	6.7
	Substitution	12.3	9.3	1.4	0.0	1.3
	Other	10.3	10.0	3.6	3.6	6.3

WS, Williams syndrome.

groups much lower levels. Figure 1 shows the performance levels (% correct) for the WS group on existing verbs in Tasks 1 and 2, and the level of regularisation for novel verbs in Task 1, with participants ordered by chronological age from left to right. The pattern of this group as a whole is one of superior performance on regular past tense formations compared to irregulars. However, there are exceptions with individuals exhibiting quite different patterns to the group mean. This emphasises the difficulty of using very small sample sizes or single case studies when working with rare developmental disorders. For example, if we had used only a single WS case study and only Task 1, we could have by chance found evidence to support the claim that individuals with WS show equal levels of performance on irregular and regular past tense forms (participants 4, 9, and 11 show this pattern). If we had used both tasks, for two of these participants (4 and 11), we would have found that in Task 2, performance on regulars was now better than that on irregulars. But participant 9 still shows equal performance on regulars and irregulars in both tasks (at 55% in Task 1, at 65% in Task 2). In addition to participant 9, other "chance" WS case studies include: near perfect regulars at 94%, and very impaired irregulars at below 30% (Task 1, participant 2); regulars and irregulars both perfect at 100% (Task 1, participant 21, Task 2, participant 19); regulars and irregulars both very impaired at less than 25% (both tasks, participant 18). If we make the assumption that a syndrome such as Williams is characterised by a single cognitive architecture, masked by individual differences and task-specific factors, then these results suggest that it is as crucial as with the typical population to examine as large a population as possible, in order to adequately characterise the relevant cognitive architecture.

Comparison of the WS and control groups

An initial comparison of the WS group with the performance of individual control groups showed that their performance most resembled that of the 6-year-old group, in terms of the proportions of each response type that they produced. As a broad metric of similarity (and therefore not correcting for the number of tests), we compared the response rates for the WS group and the 6-year-olds in each of the four main response categories (regularise, irregularise, unmark, substitute) for each of the six stimulus sets (Task 1 regular, irregular, novel non-rhyme, novel rhyme, Task 2 regular, irregular), in the form of 24 between-participant *t*-tests. These tests showed no significant differences at the .05 level. By comparison, when the WS group was compared to the 8-year-old group across these 24 cells, there were 12/24 significant differences; in comparison to the 10-year-

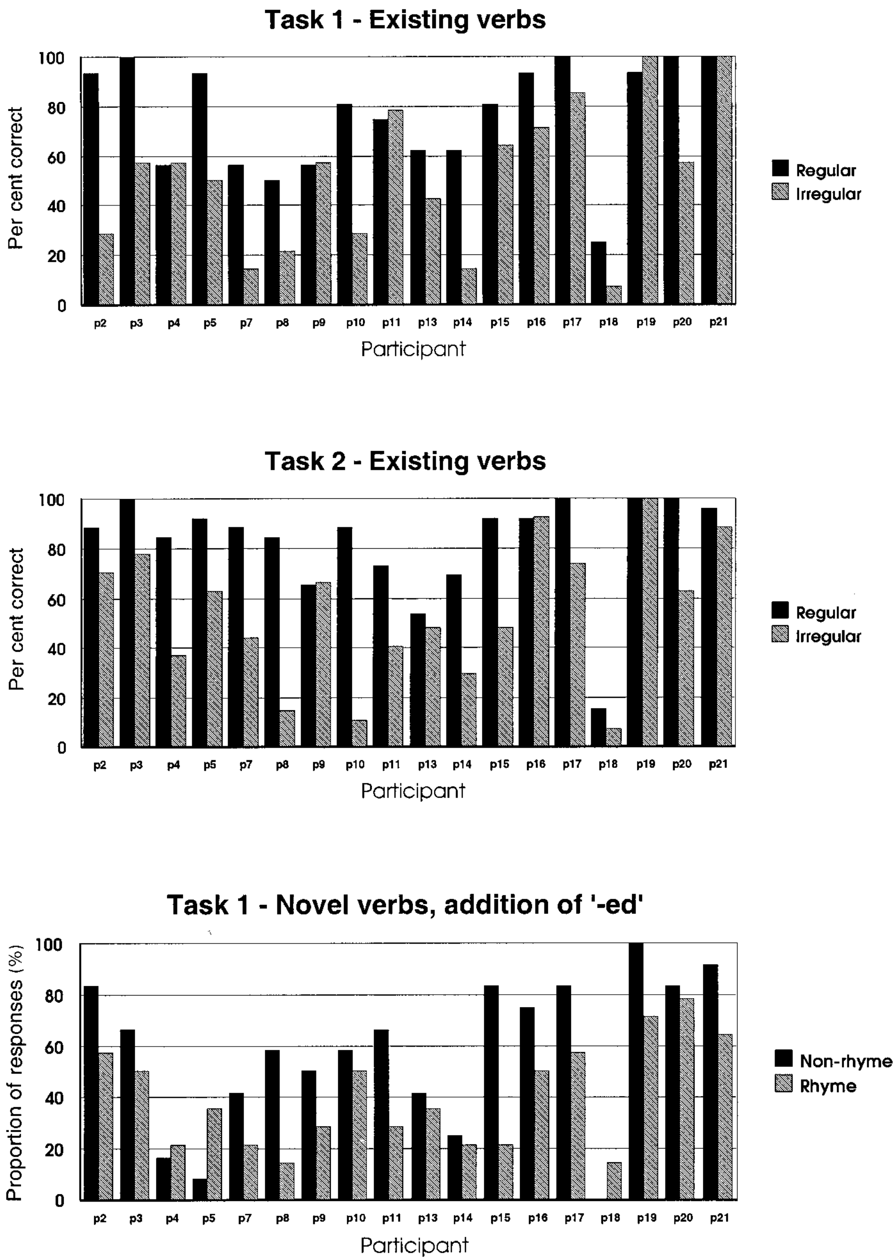

Figure 1. Performance (% correct) of participants with Williams syndrome on the past tense elicitation task for regular and irregular verbs in Task 1 and Task 2, and levels of regularisation for novel non-rhymes (e.g., brop) and novel rhymes (e.g., crive) in Task 1.

olds, there were 12/24 significant differences; and in comparison to the adult group, 17/24 significant differences.

However, the fact that the WS group was not significantly different to the 6-year-old group may in part reflect the variability within the WS responses as shown in Figure 1. The main aim of this study was to build a developmental profile to examine how performance on Tasks 1 and 2 changed with increasing age, and to see whether the WS participants fitted this profile given their level of language ability. In accordance with this aim, we ran two sets of linear regression analyses, which sought to establish the relationship between past tense performance and increasing age. In the first case, we examined the relationship between performance and chronological age (CA), building interaction terms into the model to allow us to compare the performance of the normally developing group with that of the WS group, to compare the performance on regular verbs with that on irregular verbs, and to examine whether there was a differential effect of verb type between the participant groups. (Repeated measures were handled within the regression analyses by using the criterion scaling method; see Pedhazur, 1997, for a description, along with a general discussion of linear regression techniques.) We expected the performance of individuals with WS to be poorer given their delayed language development. In the second case, we examined the relationship between performance and increasing verbal mental age (VMA), including the same interaction terms. For the WS group, VMA was taken as the average test age for the Word Definitions and the Verbal Similarities subtests of the BAS–II. As an approximation, we took the VMA of the control participants to be the same as their chronological age, given that their class teachers were asked to avoid selecting children who were either particularly advanced or delayed relative to the general level of the class, and that our aim was to build a developmental profile. A ceiling of 18;0 was used for generating the VMAs for controls in line with the maximum test age achievable on the standardised language tests. This second analysis allowed us to test whether the participants with WS had a disadvantage on irregular verbs over and above that which we would expect for their level of language development. To give an indication of how performance changes with increasing chronological and verbal mental age, Figures 2–5 show WS and control performance when sorted into CA and VMA bins which capture the distribution of the respective ages across the two samples.

In order to generate meaningful results using the linear regression analyses, it is important to establish that the relationship between performance and age is indeed a linear one. However, Figures 2–5 clearly demonstrate ceiling effects in the performance measures. In order to linearise this relationship, we took the inverse of the squares of chronological age and verbal mental age as the factors to be included in the regression analyses. Thus although for brevity we will refer to them as CA and VMA, the age factors in the following analyses were actually $1/(CA)^2$ and $1/(VMA)^2$, with age measured in months.

Existing verbs

Although correct performance in Task 2 was better than that in Task 1 by approximately 4% [related samples *t*-test, $t = 3.28$, df $= 127$, $p = .001$], this was a small effect. When Task was added as a factor in the regression model relating chronological age to performance in both tasks, it did not pick up a significant amount of variance [fit of model to data: $R = .98$, $N = 128$, $F(14,61) = 124.32$, $p < .001$; main effect of Task: $F(1,61) = 1.48$, $p = .229$] nor show significant interactions with participant group [$F(1,61) = 0.67$, $p = .418$]. This was also the case when verbal mental age was related to performance in both tasks [fit of model to data: $R = .98$, $N = 128$, $F(14,61) = 126.10$, $p < .001$; main effect of Task: $F(1,61) = .60$, $p = .443$; interaction of Task and participant group: $F(1,61) = .03$, $p = .866$]. For conciseness, the following section describes performance according to a single composite score on both tasks, since the pattern was the same when each task was analysed separately.

Analyses controlling for chronological age

In the following analyses, the four control groups were combined into a single typically developing control group. A linear regression analysis was carried out predicting correct performance on the basis of chronological age, verb type (regular/irregular; repeated measure), and participant group (WS/control). Two interaction terms were included which examined whether the relationship between correct performance differed between the two participant groups, and whether the difference between performance on regular and irregular verbs was affected by the group variable. This latter term should tell us whether the WS group showed a greater disparity between irregulars and regulars than that found in the control group. Figure 2 shows the distribution of the scores across CA for the two groups. The regression analysis produced a significant fit to the data [$R = .96$, $N = 128$, $F(6,61) = 106.02$, $p < .001$]. The results showed a significant relationship between increasing chronological age and correct performance [$F(1,61) = 31.02$, $p < .001$], which was significantly modulated by verb type such that irregular verbs showed poorer performance than regular verbs [$F(1,61) = 31.90$, $p < .001$]. As expected, when chronological age was controlled for, the performance of the WS group was significantly lower than that of the typically developing group [$F(1,61) = 37.00$, $p < .001$]. In addition, the difference in performance was

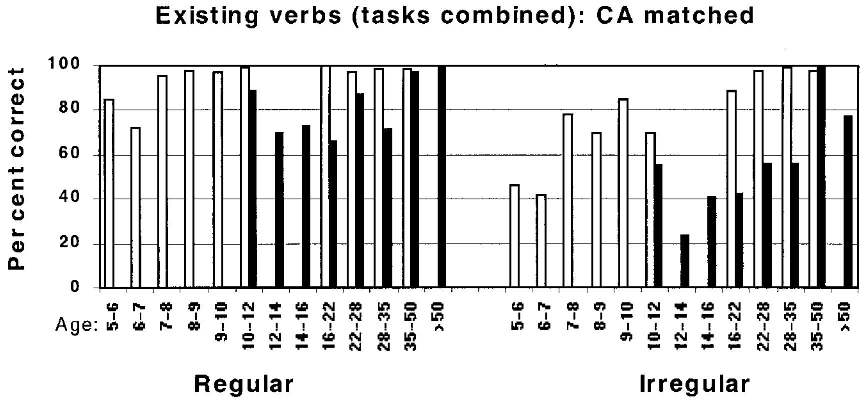

Figure 2. Comparison of levels of correct past tense production for Williams syndrome (■) and typically developing groups (□) on regular and irregular verbs for tasks 1 and 2 combined, across increasing chronological age (CA). Scores show means for a representative set of age groups across the full range.

greater for irregular verbs than regular verbs [$F(1,61) = 19.24$, $p < .001$]. This first analysis would seem to support the claim that participants with WS have a selective deficit on irregular verbs.

Analyses controlling for verbal mental age

The preceding analyses were repeated but now relating correct performance to increasing verbal mental age. Figure 3 shows the distribution of performances for the WS and typically developing groups across VMA. The regression model again showed a significant fit to the data [$R = .95$, $N = 128$, $F(6,61) = 97.18$, $p < .001$], and a significant relationship between performance and increasing VMA [$F(1,61) = 50.37$, $p < .001$]. The results showed that verb type once more modulated the relationship between the correct performance and age, with regular verbs demonstrating higher performance than irregular verbs [$F(1,61) = 100.16$, $p < .001$]. The effect of participant group was reduced but still significant [$F(1,61) = 7.04$, $p = .010$], such that the performance of the WS group was still worse even when matched according to our measure of VMA. Importantly, however, there was now no significant interaction of participant group with verb type [$F(1,61) = .75$, $p = .390$]. The WS group showed the same difference between performance on regular and irregular verbs as the typically developing group. There was no specific additional deficit for irregular verbs.

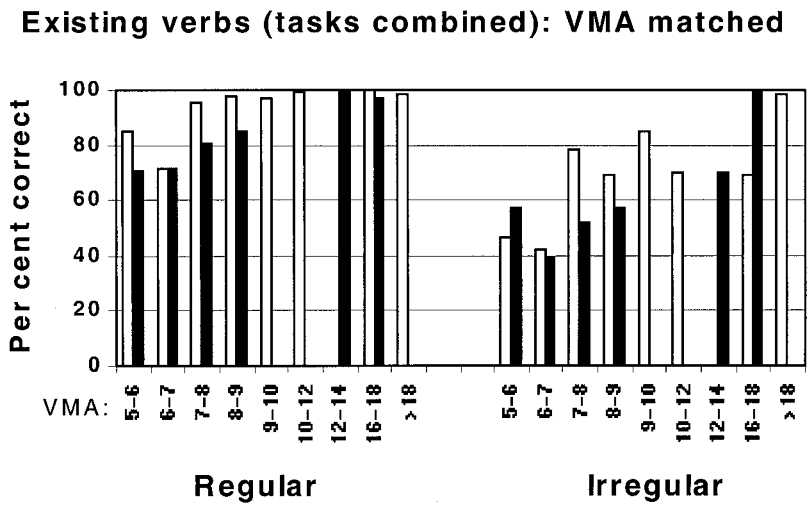

Figure 3. Comparison of levels of correct past tense production for Williams syndrome (■) and typicall developing groups (□) on regular and irregular verbs for tasks 1 and 2 combined, across increasing verbal mental age (VMA). VMA has a ceiling of the oldest test age achievable on the relevant British Abilities Scale subtests.

Analysis of errors

In this section, we will only consider errors that participants made on irregular verbs, since these are the stimuli where individuals with WS are purported to have a specific deficit. In particular, we will focus only on the two largest error types, regularisation of these verbs, and reproducing the unmarked stem. Direct comparison of the proportions of each error made by a group is compromised by the fact that these distributions are not independent, increasing the chance of Type 1 errors. Nevertheless, regression analyses showed a strong three-way interaction of task, participant group, and error type in relating rate of regularisation and unmarking errors to CA and VMA (CA: fit to model: $R = .93$, $N = 256$, $F(14{,}61) = 26.97$, $p < .001$, Task × Group × Error type interaction: $F(1{,}61) = 14.26$, $p < .001$; VMA: fit to model: $R = .93$, $N = 256$, $F(14{,}61) = 29.16$, $p < .001$, Task × Group × Error type interaction: $F(1{,}61) = 4.71$, $p = .034$). The interaction suggests that task demands had a differential effect on the two participant groups. In both groups, the shift from Task 1 to 2 reduced the levels of unmarking errors, while the overall levels of performance remained approximately the same. Thus the demands of Task 1, with its higher memory load, promoted unmarking errors over regularisation errors for irregular verbs, while Task 2 promoted regularisation errors over unmarking errors. This effect was stronger in the WS group.

However, inspection of Table 3 reveals that the WS group as a whole exhibited the same pattern of errors on irregular verbs as the 6-year-old group in both Tasks 1 and 2: more unmarking than regularisation errors in Task 1, more regularisation errors than unmarking errors in Task 2. What, then, is the source of the differential group effect? The interaction arises from the fact that half of the WS group have verbal mental ages in *excess of 6 years*. In other words, the differential effect arises because the participants with WS who have higher VMAs persist in showing an immature pattern of errors in Task 1, a pattern in which unmarking errors are produced in response to higher memory loads.

Novel verbs

The most common response to novel verbs for all participant groups was regularisation. We compared the levels of regularisation for novel verbs which did not rhyme with existing irregulars (e.g., brop) against those which did (e.g., crive), using the same regression model as with the existing verbs. Regularisation levels were predicted on the basis of chronological age, item type (non-rhyme/irregular-rhyme; repeated measure), and participant group (WS/control), with two interaction terms to check for interactions of item type with chronological age, and item type with participant group.

Figure 4 shows the distribution of the scores across CA for the two groups. The regression analysis produced a significant fit to the data [$R =$

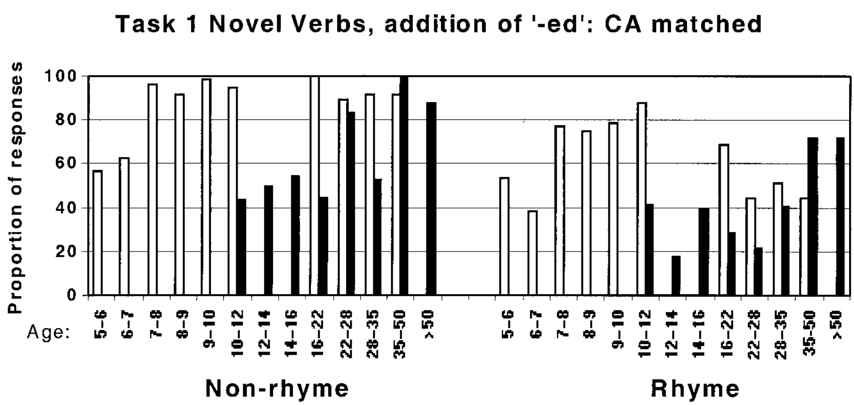

Figure 4. Comparison of levels of regularisation of novel non-rhymes (e.g., brop) and rhymes (e.g., crive) for Williams syndrome (■) and typically developing groups (□) in Task 1, across increasing chronological age (CA).

.95, N = 128, $F(6,61) = 91.27$, $p < .001$]. The results demonstrate a significant relationship between increasing chronological age and novel verb regularisation [$F(1,61) = 5.37$, $p = .024$]. This relationship was significantly modulated by item type such that novel items not rhyming with existing irregular verbs were regularised more than those that did rhyme [$F(1,61) = 101.05$, $p < .001$], consistent with the notion that the similarity of the novel terms to irregulars interfered with regularisation. When chronological age was controlled for, the performance of the WS group in adding "-ed" to novel verbs was significantly poorer than that of the typically developing group [$F(1,61) = 25.96$, $p < .001$]. Lastly, the WS group showed significantly greater impairment in regularising rhymes than non-rhymes [$F(1,61) = 8.92$, $p = .004$].

Figure 5 depicts the distribution of the scores across VMA for the two groups. When the analysis was performed using VMA, the same effects were found except that the trend for a greater impairment in the WS group on regularising rhymes had disappeared [$F(1,61) = .31$, $p = .578$], suggesting that this disparity was a consequence of language delay. There was still a strong main effect of participant group corresponding to poorer generalisation in the WS group [$F(1,61) = 13.92$, $p < .001$]. Interestingly, a regression model relating correct performance on existing verbs/regularisation on novel verbs to VMA showed that the disparity between the two

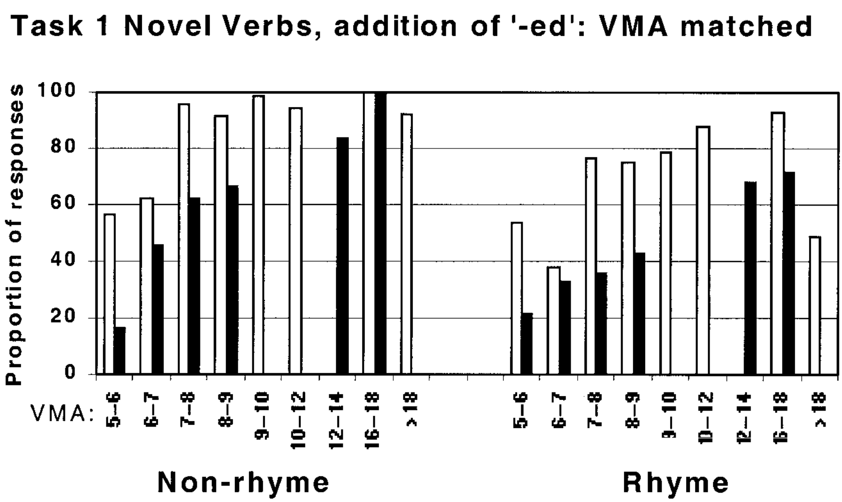

Figure 5. Comparison of levels of regularisation of novel non-rhymes (e.g., brop) and rhymes (e.g., crive) for Williams syndrome (■) and typically developing groups (□) in Task 1, across increasing verbal mental age (VMA). VMA has a ceiling of the oldest test age achievable on the relevant British Abilities Scale subtests.

groups was significantly greater for generalisation than it was for performance on existing verbs [fit of the model to data: $R = .93$, $N = 256$, $F(14,61) = 29.16$, $p < .001$; interaction of stimulus type (existing verb/novel verb) and participant group (WS/control): $F(1,61) = 4.02$, $p = 0.049$]. That is, the WS group appeared to have an additional deficit in generalising regular past tense formation to novel verbs.

Lastly, we examined the levels of irregularisation of novel rhymes. Our control groups showed low levels of irregularisation (6 years: 6.4% 8 years: 6.4%, 10 years: 10.0%, adults: 34.3%), much more in line with van der Lely and Ullman's (this issue) control data than those of Clahsen and Almazan (1998). The WS group showed lower levels of irregularisation, at 4.8%. Regression analyses which used the untransformed ages gave a better fit to the data here than the $1/age^2$ transform. These analyses showed a significant relationship between irregularisation levels and CA but also an effect of participant group, with the WS group producing less irregularisations [fit of model: $R = .63$, $N = 64$, $F(2,61) = 20.07$, $p < .001$, group effect: $F(1,61) = 21.56$, $p < .001$]. However, this difference became non-significant when VMA rather than CA was controlled for [fit of model: $R = .67$, $N = 64$, $F(2,61) = 25.45$, $p < .001$; group effect: $F(1,61) = 1.76$, $p < .190$]. Unlike with regularisation, the lower level of irregularisation in the WS group was not significant once language ability was controlled for.

Frequency and imageability effects

We examined frequency effects in production rates on existing regular and irregular verbs in Task 1 using the high and low frequency sets employed by van der Lely and Ullman (2000). For Task 2, we had a larger stimulus set, permitting more sensitive contrasts. We compared performance on the 10 most frequent verbs with that on the 10 least frequent verbs, with frequencies taken from the CELEX database (Baayan, Piepenbrock, & van Rijn, 1993). Mean frequencies for each verb type are shown in Table 4. We performed these comparisons twice, once using the frequency of the verb root to define the high and low frequency groups, once using the frequency of the past tense form. This made little difference to the results. For each participant group (WS, 6, 8, 10, and adult), we performed a related samples t-test between performance on high and low frequency verbs of each type. The mean scores are shown in Table 5.

In Task 1, no control group showed a significant frequency effect for either regular or irregular verbs (all $p > .35$). In Task 2, no control group showed a significant frequency effect for regular verbs. However, the 6-year-old, 8-year-old and 10-year-old groups showed a significant frequency effect for irregular verbs (*root frequency*: 6 years $t = 4.15$, df $= 9$, $p = .002$,

TABLE 4
Mean frequency and imageability ratings for the stimuli in Task 2

		Frequency (per million words)					*Imageability (mean verb root frequency)*		
			Verb root frequency		*Past tense frequency*				
		N	*High*	*Low*	*High*	*Low*	*N*	*High*	*Low*
Regular	mean	10	67	3	48	2	6	515 [7]	395 [42]
	std		45	1	49	1		25 [6]	39 [32]
Irregular	mean	10	42	2	45	2	7	544 [6]	342 [52]
	std		19	1	49	1		27 [3]	37 [55]

Frequency ratings are combined written and spoken frequencies taken from the CELEX database (Baayan, Piepenbrock, & Rijn, 1993). Imageability ratings are from Coltheart (1981). std = standard deviation.

TABLE 5
Effects of frequency and imageability in past tense production

			Correct response (%)				
Task	*Verb type*		*WS*	*6*	*8*	*10*	*Adult*
Task 1	Existing regular	High frequency	83.3	71.3	96.3	98.8	97.7
		Low frequency	70.1	76.3	92.5	96.3	98.4
	Existing irregular	High frequency	46.5	42.5	65.0	72.5	86.7
		Low frequency	50.8	35.7	62.9	70.0	92.0
Task 2	Existing regular	High frequency+	85.0/85.0	81.0/79.0	100.0/100.0	99.0/98.0	100.0/98.8
		Low frequency+	78.9/76.1	81.0/78.0	99.0/99.0	97.0/96.0	97.5/97.5
	Existing irregular	High frequency+	52.2/55.6	49.0/50.0	84.0/88.0	87.0/90.0	98.1/98.1
		Low frequency+	49.4/51.1	30.0/29.0	64.0/65.0	77.0/76.0	95.6/95.6
Task 2	Existing regular	High imageability	77.8	81.7	100.0	96.7	97.9
		Low imageability	83.3	75.0	100.0	98.3	97.9
	Existing irregular	High imageability	65.9	55.7	87.1	88.6	98.2
		Low imageability	50.8	48.6	84.3	87.1	98.2

WS, Williams syndrome; + root frequency/past tense frequency.

8 years $t = 2.37$, df $= 9$, $p = .042$, 10 years $t = 1.46$, df $= 9$, $p = .177$; *past tense frequency*: 6 years $t = 3.28$, df $= 9$, $p = .010$, 8 years $t = 3.02$, df $= 9$, $p = .014$, 10 years $t = 2.33$, df $= 9$, $p = .045$). The presence of frequency effects for irregulars but not regulars in our younger control groups replicates the typical pattern seen in past tense elicitation tasks (Pinker, 1991, 1999).

The WS results for frequency are surprising. The WS group showed no frequency effect for irregulars in either task (all $p > .3$). However, they displayed a frequency effect for *regular* verbs in both Task 1 ($t = 2.64$, df = 17, $p = .017$) and Task 2 (*root frequency*: $t = 2.27$, df = 17, $p = .037$; *past tense frequency*: $t = 2.41$, df = 17, $p = .028$). Non-parametric sign tests on these three comparisons yielded p-values of .002, .073, .073. Thus they remained at least as trends using tests with much reduced statistical power. This pattern of frequency effects for regular but not irregular verbs is very unusual.

Established imageability ratings were only available for a subset of the verbs in Task 2 (Coltheart, 1981). Mean performance on the six most and six least imageable regular verbs (high: *kick*, *dance*, *leak*, *laugh*, *graze*, *walk*; low: *raise*, *call*, *move*, *stay*, *save*, *balance*) and the seven most and seven least imageable irregular verbs (high: *weep*, *ring*, *drink*, *sing*, *stick*, *sting*, *hang*; low: *grow*, *lose*, *learn*, *keep*, *come*, *chose*, *deal*) was compared across the control groups. Mean imageability scores are given in Table 4. The results showed no effect of imageability for regular or irregular verbs in any control group (all $p > .25$). The WS group did not show an effect of imageability on regular verbs. However, there was a significant effect of imageability for irregular verbs, whereby past tense forms for high imageability verbs were produced more accurately than those for low imageability verbs (high: 65.9%; low: 50.8%: $t = 2.37$, df = 17, $p = .030$). Note that frequency could not explain this effect since low imageability verbs had higher frequency than high imageability verbs. Significantly, the WS group made more regularisation errors on the low imageability verbs than on the high (high: 19.8%; low: 36.5%; $t = 2.62$, df = 17, $p = .018$). Sign tests for these two comparisons yielded p-values of .059 and .011. These results seem to imply that semantic representations were playing a role in the production of irregular past tense forms in the WS group, but not in typical controls. These effects may be important clues to the nature of the WS language system. It should nonetheless be noted that small item sets were used, and imageability ratings were made by typical adults which (as with frequency ratings) may have limited validity for atypical populations.

DISCUSSION

The main result of this study is that, in contrast to the findings of Clahsen and Almazan (1998) and Bromberg et al. (1994), individuals with WS showed no selective deficit in their production of irregular English past tense forms. We compared the performance of 21 individuals with WS against that of a normal developmental profile constructed using 46 control participants with ages varying from 5;5 to 45;0. When the verbal mental age of the WS group was controlled for, the difference in performance levels between the groups was very much reduced and importantly, the WS group now showed the same relation between performance on regular and irregular verbs as the typically developing group. Controlling for verbal mental age (VMA) did leave a residual effect of worse overall performance in the WS group. However, this may be because the standardised tests we employed overestimated these participants' language ability, since the tests measured vocabulary rather than syntax. A number of studies have shown that standardised tests of vocabulary with individuals with WS produce test ages in advance of those found on tests of grammar (Clahsen & Almazan, 1998; Grant et al., 1997; Karmiloff-Smith, Grant, Berthoud, Davies, Howlin, & Udwin, 1997; Volterra, Capirci, Pezzini, Sabbadini, & Vicari, 1996). Controlling for syntax rather than vocabulary would have placed the WS group lower on the control profile and it is possible the overall difference in performance would have disappeared.

The second important finding was that, when VMA had been controlled for, the WS group showed an additional deficit in generalising the "add -ed" past tense rule to novel forms, a deficit greater than the residual disparity between the groups for existing verbs. The deficit in generalisation appeared to be over and above that caused by a delay in development. With regard to the irregularisation of novel verbs rhyming with existing irregulars, both the WS group and the control group showed low levels of such generalisation. When VMA was controlled for, irregularisation of rhymes in the WS group was lower but not significantly discernible from the control group ($p = .190$). This again contrasts with the findings of Clahsen and Almazan, a disparity which appears largely due to the much higher rates of irregularisation reported for the control participants in that study than in any other published study on normal controls.

Thirdly, we found a significant effect of task demands in determining the patterns of errors produced for irregular verbs. A between-task comparison revealed that Task 1 promoted errors of unmarking in young controls, but that Task 2 promoted errors of regularisation. However, participants with WS persisted in showing unmarking errors in Task 1 at VMAs when they had disappeared in the control group. Responses in Task 1 involved repetition of at least a sentence fragment whereas those in Task 2 only required completion of a single word when the initial sound had been provided. It is possible, then, that in younger control participants, the additional memory component in Task 1 caused errors of omission that became errors of commission in Task 2. Participants with WS remained sensitive to the memory component of Task 1 at levels of language ability when they had ceased to affect the control group. It is not clear whether this difference reflects a deficit specific to WS or is linked to the general mental retardation in this syndrome. Nevertheless, the role of task demands in determining error types in this study demonstrates that one should be cautious in reading too much into the results of a single procedure, particularly in research with atypical populations where working memory and metacognition may be weaker than in the typically developing population.

Fourthly, the results of this study highlighted how potentially misleading single case studies may be. We found a number of patterns of behaviour in our WS sample, including very high performance on both regulars and irregulars, very low levels on both regulars and irregulars, equal intermediate performance on both verb types, and very high regular performance with low irregular performance (as with the controls, no participant showed much higher irregular verb performance then regular performance). Each of the above patterns, if used as a case study, would have led to totally different conclusions about the WS language system. Yet inspection of Figures 2–5 is persuasive evidence that we are predominantly witnessing a delayed system, rather than a normal one with a selective deficit in irregular past tense formation.

However, several pieces of evidence suggest that it would be wrong to characterise the WS language system as simply delayed. We have already seen the additional deficit in generalisation compared to performance on existing verbs. Examination of factors underlying past tense production, specifically verb frequency and verb imageability, also produced unusual patterns. Effects of frequency have been taken as a marker for associative lexical memory processes in the production of past tense forms (Pinker, 1991, p. 532). For example, when van der Lely and Ullman (2000) found frequency effects in regular past tense formation of participants with SLI, they interpreted the results in terms of Pinker's dual-mechanism model. They took the frequency effect to imply that, lacking the rule-mechanism to perform *-ed* suffixation, the SLI group was memorising regular past tense forms as well as irregulars. Given that Pinker (1991) and Clahsen and Almazan (1998) take WS to represent the opposite case—a system with an intact rule-mechanism but impaired lexical memory—we should *definitely not* expect to find frequency effects in the formation of regular past tense in our WS sample. However, unlike controls, participants with WS were significantly more accurate at forming high frequency regular past tenses than low frequency. Just as surprisingly, the WS group showed no frequency effects for irregular verbs, in contrast to control participants. This pattern of frequency effects is not readily explained by any current model, but particularly strains the straightforward logic of the dual-mechanism model.

With regard to imageability, an effect of this semantic dimension on the accuracy of past tense formation would seem to implicate lexical memory in this grammatical process. The control group, however, showed no effect of this variable. While the WS group also showed no effects of imageability on regular verbs, they did demonstrate superior performance on high rather than low imageability irregular verbs. In addition, low imageability irregular verbs showed greater levels of regularisation errors. If we assume that high imageability verbs generate a more robust semantic representation, these findings imply that in WS, semantics is playing a role in preventing the regularisation of irregular verbs.

The position we wish to argue for in the rest of this discussion is that WS does not merely represent a case of delayed language development, but a case of language development following an atypical developmental trajectory. We will outline what we believe that trajectory to be shortly. Firstly, however, we wish to emphasise the contrast that exists between viewing developmental disorders as atypical trajectories of development and viewing them as if they were cases of normal development with specific deficits (in the way that cases of adult brain damage are described).

Karmiloff-Smith (1998) has argued that to conceive of developmental disorders as if they were cases of selective deficits to processing modules identified in the adult system omits the essential role of development in producing behavioural deficits in these disorders. The disordered system is one that has followed a long trajectory of development shaped by both initial low-level neurocomputational impairments and subsequent interaction with the environment. If there are behavioural deficits in the outcome of development, these are likely to be the result of a cognitive system which has developed under a different set of constraints. The *neuroconstructivist approach* (Elman et al., 1996; Karmiloff-Smith, 1998) views developmental disorders in terms of different developmental trajectories, caused by initial differences at a neurocomputational level (see also Karmiloff-Smith & Thomas, in press; Mareschal & Thomas, in press; Oliver et al., 2000; Thomas & Karmiloff-Smith, 2000). Thus there might be differences in the local connectivity of the brain or the firing properties of neurons, as opposed to discrete lesions to particular large-scale brain structures or pathways. In this view, development is an interactive process in which the cognitive system self-organises in response to interactions with a structured environment. A deficit at the behavioural level may not imply damage to a particular mechanism in an otherwise normal system. Rather, it may point to a system that has developed throughout in a qualitatively different fashion in response to different initial constraints. Indeed, neuroconstructivism suggests that even when behaviour is equivalent across normal and abnormal phenotypes, this may mask different underlying cognitive processes. The notion that an ability is "intact" or "spared" because there is no apparent deficit at the behavioural level employs terminology from the adult brain damage model that may be misleading in the case of developmental disorders.

In the case of the WS language system, there is (as yet circumstantial) evidence to suggest that the constraints under which this system has developed involve a different balance between semantic and phonological information, specifically a greater reliance on phonology and relatively weaker semantics. The following evidence is consistent with this view. Children with WS display auditory sensitivity and (relative to their other capacities) good short-term memory for words and digits from as young as 2;6, the youngest age tested (Mervis & Bertrand, 1997). During vocabulary acquisition in WS, the naming spurt precedes fast-mapping ability, whereas in typical development these two are associated, suggesting vocabulary growth in WS is more reliant on phonology (Mervis & Bertrand, 1997). Furthermore, the naming spurt in WS is not associated with exhaustive category sorting, a marker of maturing semantic representations, once more suggesting that vocabulary growth is less reliant on semantics (Mervis & Bertrand, 1997). Although local semantic organisation seems normal in WS in terms of priming effects (Tyler et al., 1997) and category fluency (Mervis et al., 1999), global semantic organisation remains immature (Johnson & Carey, 1998). A reduced contribution of semantics was also apparent in a study that looked at sentence processing. Karmiloff-Smith et al. (1998) found that when WS participants were monitoring sentences for a target word, they did not show sensitivity to subcategory violations (e.g., ‘‘The burglar was terrified. He continued *to struggle the dog* but he couldn’t break free.’’) The authors took this to suggest that in WS, semantic information may become available too slowly to be integrated with the on-line processing of syntax. In WS, phonological encoding displays the normal patterns, but again there is a claim with respect to a reduced contribution of semantic information to short term-term memory for words (Vicari, Brizzolara, Carlesimo, Pezzini, & Volterra, 1996; Vicari, Carlesimo, Brizzolara, & Pezzini, 1996). Lastly, a recent study of reading in WS came to similar conclusions about the role of phonology over weaker constraints from semantics (Laing, Hulme, & Karmiloff-Smith, 2000). In this study, the WS group, but not the controls, showed equal levels of reading for concrete and abstract words.

Taken together, these studies paint a picture of WS in which, unlike in typical development, phonology plays a greater role than semantics during early language development. Moreover, as a consequence of early auditory sensitivity, the phonological representations themselves may be atypical. Reduced levels of generalisation of inflectional patterns in the current study and in a French gender task by Karmiloff-Smith et al. (1997) are consistent with the view that in WS, phonological representations may be too specific to support robust generalisation. However, it has also been argued that WS is characterised by impaired semantic lexical representations (e.g., Rossen et al., 1996). That is, the differential constraints in WS language development may involve both atypical phonology and weaker semantics. Therefore, we have two possible candidates to explain the performance of the WS group in past tense formation.

Computational modelling has allowed us to explore the relative merits of each account. In contrast to the dual-mechanism model, an alternative theory suggests that past tense performance may be achieved by a single device which learns associations between the phonological forms of verb stems and past tense forms (Daugherty & Seidenberg, 1992; Joanisse & Seidenberg, 1999; MacWhinney & Leinbach, 1991; Plunkett & Juola, 1999; Plunkett & Marchman, 1991, 1993; Rumelhart & McClelland, 1986; see Thomas & Karmiloff-Smith, 2000, for a recent comparison of the two theories). Connectionist models of the development of past tense formation embody this alternative theory. These computational models are learning systems which readily allow us to address the effect of initial system constraints on the subsequent developmental trajectory.

In this way, Thomas and Karmiloff-Smith (2000) have explored how changes in the initial constraints of a connectionist model of past tense formation in the normal population (Plunkett & Marchman, 1991) affect its endstate performance. This model focused on the implications of acquiring the past tense with atypical phonological representations. In particular, in line with evidence of an early (relative) strength in auditory short-term memory and the reported hypersensitivity of the auditory system in adults with Williams syndrome (McDonald, 1997; Neville, Mills, & Bellugi, 1994), the initial phonological representations were altered to increase the discriminability between the sounds making up each word. When the system was trained at the normal rate using these altered representations, the network showed delayed development, a consequent apparent deficit for irregular verbs, and reduced generalisation to novel items. Many other initial constraints were varied, but the phonological manipulation alone produced a robust fit to all three features of the WS data. Importantly, when the model was simply run with a slower rate of development, a reduction in generalisation to novel past tense forms did not result. In short, our model supported the viability of the account that atypical phonology might explain the three performance deficits of individuals with WS in past tense formation.

A similar model by Hoeffner and McClelland (1993) has captured some aspects of past tense performance in SLI. In contrast to the WS model, the SLI model showed poorer performance on regular than irregular verbs. The SLI model also used atypical phonological representations throughout training, but in this case, phonological representations that were *impoverished* rather than overly-detailed. In some senses, then, these two models retain the opposite relationship of WS and SLI proposed by Pinker (1991), but now within a developmental computational framework rather than an adult deficit framework. In addition, taken together, these two *single system* models demonstrate a developmental double dissociation between regular and irregular verb performance. The fact that performance on regular and irregular verbs can dissociate in models which do not include separate structures for each verb type undermines the inference that developmental double dissociations necessarily reveal structure within the cognitive system, let alone innate structure (see Thomas & Karmiloff-Smith, 2000, for further discussion).

The Thomas and Karmiloff-Smith (2000) model did not include semantics, however, so that it could not account for the imageability effects in the WS group in the current study. Could a weak semantic system form an alternative account of WS past tense deficits? Joanisse and Seidenberg (1999) developed a connectionist model of past tense formation including semantics, designed to account for how adults with brain damage could show differential degrees of impairment in either regular or irregular past tense formation. They proposed that the association between the phonological forms of stem and past tense is mediated by semantic information. The primary role of semantic information in this system is to aid production of irregular forms (an idea also proposed in models of word reading, see Plaut, McClelland, Seidenberg, & Patterson, 1996). If the semantic representations in this model are damaged, the result is greater impairment for irregular forms, capturing the pattern of deficits found in some patients with Alzheimer's disease and posterior aphasics (Ullman et al., 1997). The model suggests a role for semantics in the production of irregular past tense forms in normal development. If our hypothesis concerning the reduced efficiency of semantics in WS is correct, then the expression of imageability effects in the WS group's production of irregular verbs becomes readily interpretable. Low imageability verbs provide a weaker semantic input to the system so that the chance of over-regularisation increases. Paradoxically, the presence of a semantic effect in the WS group but not the control group may reflect a *weaker* semantic system than in the control group.

However, it is not clear from the Joanisse and Seidenberg (1999) model that weaker semantics alone would be sufficient to account for the delayed development and the reduction in generalisation we find in WS past tense formation, or that semantics would play the same role in the atypical case as the typical case if it were impaired at the outset of development rather than the end. Further computational modelling work remains to be done that perhaps combine aspects of both the phonological and semantic models.

CONCLUSION

Previous approaches have suggested that in terms of language, WS is a syndrome where syntax is "intact". Thus an apparent deficit in irregular past tense formation was attributed not to syntactic mechanisms but to a specific deficit in a mechanism responsible for storing information about lexical entries in an otherwise normally developing language system (Clahsen & Almazan, 1998; Pinker, 1991). In two past tense elicitation tasks with a sample of 21 participants with WS and 46 typically developing controls, we have demonstrated that (a) much if not all of the apparent deficit in irregular past tense formation is in fact a consequence of delayed language development (when verbal mental age is controlled for the selective deficit disappears); and (b) participants with WS show a number of underlying differences in generalisation, frequency effects and imageability effects, which may be clues as to why their language development is delayed. We suggested an account of language development in WS in which development occurs under different constraints, with greater weight placed on phonological information and less weight on semantic information. Computational models of the developmental process in inflectional morphology are encouraging with regard to the viability of such an account. In addition, they are consistent with a theoretical framework which, unlike the adult brain damage model, places development centre stage in explaining behavioural deficits in developmental disorders.

REFERENCES

Aram, D., Morris, R., & Hall, N. (1993). Clinical and research congruence in identifying children with specific language impairment. *Journal of Speech and Hearing Research*, *36*, 580–591.

Baayan, H., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX lexical database (CD-ROM)*. University of Pennsylvania, Philadelphia: Linguistic Data Consortium.

Baron-Cohen, S. (1998). Modularity in developmental cognitive neuropsychology: Evidence from autism and Gilles de la tourette syndrome. In J.A. Burack, R.M. Hodapp, & E. Zigler (Eds.), *Handbook of mental retardation and development* (pp. 334–348). Cambridge: Cambridge University Press.

Bellugi, U., Bihrle, A., Jernigan, T., Trauner, D., & Doherty, S. (1990). Neuropsychological, neurological, and neuroanatomical profile of Williams syndrome. *American Journal of Medical Genetics Supplement*, *6*, 115–125.

Bellugi, U., Lichenberger, L., Mills, D., Galaburda, A., & Korenberg, J.R. (1999). Bridging cognition, the brain and molecular genetics: evidence from Williams syndrome. *Trends in Neurosciences*, *22*, 197–207.

Bellugi, U., Marks, S., Bihrle, A., & Sabo, H. (1988). Dissociation between language and cognitive functions in Williams syndrome. In D. Bishop & K. Mogford (Eds.), *Language development in exceptional circumstances* (pp. 177–189). London: Churchill Livingstone.

Bellugi, U., Wang, P., & Jernigan, T.L. (1994). Williams syndrome: An unusual neuropsychological profile. In S. Broman & J. Grafman (Eds.), *Atypical cognitive deficits in developmental disorders: Implications for brain function* (pp. 23–56). Hove, UK: Lawrence Erlbaum Associates Ltd.

Bishop, D.V.M., North, T., & Donlan, C. (1995). Genetic basis of specific language impairment. *Developmental Medicine and Child Neurology*, *37*, 56–71.

Bromberg, H., Ullman, M., Coppola, M., Marcus, G., Kelley, K., & Levine, K. (1994). A dissociation of lexical memory and grammar in Williams Syndrome: Evidence from inflectional morphology. Paper presented at the Sixth International Professional Conference of the Williams Syndrome Association, San Diego, CA.

Bybee, J. & Slobin, D. (1982). Rules and schemas in the development and use of the English past. *Language*, *58*, 265–289.

Clahsen, H., & Almazan, M. (1998). Syntax and morphology in Williams syndrome. *Cognition*, *68*, 167–198.

Coltheart, M. (1981). The MRC psycholinguistic database. *Quarterly Journal of Experimental Psychology*, *33A*, 497–505.

Daugherty, K. & Seidenberg, M.S. (1992). Rules or connections? The past tense revisited. In *Proceedings of the Fourteenth Annual Conference of the Cognitive Science Society* (pp. 259–264). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Dunn, L.M., Dunn, L.M., & Whetton, C. (1982). *British Picture Vocabulary Scale*. London: NFER-Nelson.

Elliott, C.D. (1996). *British Abilities Scales II*. London: NFER-Nelson.

Elman, J.L., Bates, E.A., Johnson, M.H., Karmloff-Smith, A., Parisi, D., & Plunkett, K. (1996). *Rethinking innateness: A connectionist perspective on development*. Cambridge, MA: MIT Press.

Gopnik, M. & Crago, M.B. (1991). Familial aggregation of a developmental language disorder. *Cognition*, *39*, 1–50.

Grant, J., Karmiloff-Smith, A., Gathercole, S.A., Paterson, S., Howlin, P., Davies, M., & Udwin, O. (1997). Phonological short-term memory and its relationship to language in Williams syndrome. *Cognitive Neuropsychiatry*, *2*, 81–99.

Hoeffner, J.H. & McClelland, J.L. (1993). Can a perceptual processing deficit explain the impairment of inflectional morphology in developmental dysphasia? A computational investigation. In E.V. Clark (Ed.), *Proceedings of the 25th Child language research forum.* Stanford: Stanford University Press.

Howlin, P., Davies, M., & Udwin, O. (1998). Cognitive functioning in adults with Williams syndrome. *Journal of Child Psychology and Psychiatry*, *39*, 183–189.

Jarrold, C., Baddeley, A.D., & Hewes, A.K. (1998). Verbal and nonverbal abilities in the Williams syndrome phenotype: Evidence for diverging developmental trajectories. *Journal of Child Psychology and Psychiatry*, *39*, 511–523.

Joanisse, M.F., & Seidenberg, M.S. (1999). Impairments in verb morphology following brain injury: A connectionist model. *Proceedings of the National Academy of Science USA*, *96*, 7592–7597.

Johnson, S. & Carey, S. (1998). Knowledge enrichment and conceptual change in folk biology: Evidence from Williams syndrome. *Cognitive Psychology*, *37*, 156–184.

Karmiloff-Smith, A. (1998). Development itself is the key to understanding developmental disorders. *Trends in Cognitive Sciences*, *2*, 389–398.

Karmiloff-Smith, A., Grant, J., Berthoud, I., Davies, M., Howlin, P., & Udwin, O. (1997). Language and Williams syndrome: How intact is "intact"? *Child Development*, *68*, 246–262.

Karmiloff-Smith, A., Klima, E., Bellugi, U., Grant, J., & Baron-Cohen, S. (1995). Is there a social module? Language, face processing, and theory of mind in individuals with Williams syndrome. *Journal of Cognitive Neuroscience*, *7*, 196–208.

Karmiloff-Smith, A. & Thomas, M.S.C. (in press). Developmental disorders. In M.A. Arbib & P.H. Arbib (Eds.), *Handbook of brain theory and neural networks, 2nd edition.* Cambridge, MA: MIT Press.

Karmiloff-Smith, A., Tyler, L.K., Voice, K., Sims, K., Udwin, O., Howlins, P., & Davies, M. (1998). Linguistic dissociations in Williams syndrome: evaluating receptive syntax in on-line and off-line tasks. *Neuropsychologia*, *36*, 343–351.

Laing, E., Hulme, C., & Karmiloff-Smith, A. (2000). *Beyond reading scores: The process of learning to read in atypical development.* Manuscript submitted for publication.

MacWhinney, B. & Leinbach, J. (1991). Implementations are not conceptualizations: Revising the verb learning model. *Cognition*, *40*, 121–157.

Mareschal, D. & Thomas, M.S.C. (in press). Self-organization in normal and abnormal cognitive development. To appear in A.F. Kalverboer & A. Gramsbergen (Eds.), *Brain and behaviour in human development. A source book.* Dordecht: Kluwer Academic Publishers.

McDonald, J.L. (1997). Language acquisition: The acquisition of linguistic structure in normal and special populations. *Annual Review of Psychology*, *48*, 215–241.

Mervis, C., & Bertrand, J. (1997). Development relations between cognition and language: Evidence from Williams Syndrome. In L.B. Adamson & M.A. Romski (Eds.), *Research on communication and language disorders: Contributions to theories of language development* (pp. 75–106). New York: Brookes.

Mervis, C.B., Morris, C.A., Bertrand, J., & Robinson, B.F. (1999). Williams Syndrome: Findings from an integrated program of research. In H. Tager-Flusberg (Ed.), *Neurodevelopmental disorders* (pp. 65–110). Cambridge, MA: MIT Press.

Morris, C.A., Demsey, S.A., Leonad, C.O., Dilts, C., & Blackburn, B.L. (1988). The natural history of Williams syndrome: Physical characteristics. *Journal of Pediatrics*, *113*, 318–326.

Neville, H.J., Mills, D.L., & Bellugi, U. (1994). Effects of altered auditory sensitivity and age of language acquisition of the development of language-relevant neural systems: Preliminary studies of Williams syndrome. In S. Broman and J. Grafman (Eds.), *Atypical cognitive deficits in developmental disorders: Implications for brain function* (pp. 67–83). Hove, UK: Lawrence Erlbaum Associates Ltd.

Oliver, A., Johnson, M.H., Karmiloff-Smith, A., & Pennington, B. (2000). Deviations in the emergence of representations: A neuroconstructivist framework for analysing developmental disorders. *Developmental Science*, *3*, 1–40.

Pedhazur, E.J. (1997). *Multiple regression in behavioural research: Explanation and prediction, 3rd Edition.* London: Harcourt Brace.

Pinker, S. (1991). Rules of language. *Science*, *253*, 530–535.

Pinker, S. (1994). *The language instinct.* Penguin Books.

Pinker, S. (1999). *Words and rules.* London: Weidenfeld & Nicolson.

Pinker, S., & Prince, A. (1988). On language and connectionism: Analysis of a parallel distributed processing model of language acquisition. *Cognition*, *28*, 73–193.

Plaut, D.C., McClelland, J.L., Seidenberg, M.S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review*, *103*, 56–115.

Plunkett, K., & Juola, P. (1999). A connectionist model of English past tense and plural morphology. *Cognitive Science*, *23*, 463–490.

Plunkett, K., & Marchman, V. (1991). U-shaped learning and frequency effects in a multi-layered perception: Implications for child language acquisition. *Cognition*, *38*, 1–60.

Plunkett, K., & Marchman, V. (1993). From rote learning to system building: acquiring verb morphology in children and connectionist nets. *Cognition*, *48*, 21–69.

Rossen, M., Bihrle, A., Klima, E.S., Bellugi, U., & Jones, W. (1996). Interaction between language and cognition: Evidence from Williams syndrome. In J.H. Beitchman, N. Cohen, M. Konstantareas, & R. Tannock (Eds.), *Language learning and behaviour* (pp. 367–392). New York: Cambridge University Press.

Rumelhart, D.E., & McClelland, J.L. (1986). On learning the past tense of English verbs. In J.L. McClelland, D.E. Rumelhart, & the PDP Research Group (Eds.), *Parallel distributed processing: Explorations in the microstructure of cognition, Vol. 2: Psychological and biological models* (pp. 216–271). Cambridge, MA: MIT Press.

Singer Harris, N.G., Bellugi, U., Bates, E., Jones, W., & Rossen, M. (1997). Contrasting profiles of language development in children with Williams and Down syndromes. *Developmental Neuropsychology*, *13*, 345–370.

Tassabehji, M., Metcalfe, K., Karmiloff-Smith, A., Carette, M.J. Grant, J., Dennis, N., Reardon, W., Splitt, M., Read, A.P., & Donnai, D. (1999). Williams syndrome: Use of chromosomal micro-deletions as a tool to dissect cognitive and physical phenotypes. *American Journal of Human Genetics*, *64*, 118–125.

Temple, C. (1997). *Developmental cognitive neuropsychology*. Hove: Psychology Press.

Thal, D., Bates, E., & Bellugi, U. (1989). Language and cognition in two children with Williams syndrome. *Journal of Speech and Hearing Research*, *32*, 489–500.

Thomas, M.S.C., & Karmiloff-Smith, A. (2000). *Modelling language acquisition in atypical phenotypes.* Manuscript submitted for publication.

Tyler, L., Karmiloff-Smith, A., Voice, J.K., Stevens, T., Grant, J., Udwin, O., Davies, M., & Howlin, P. (1997). Do individuals with Williams syndrome have bizarre semantics? Evidence for lexical organization using an on-line task. *Cortex*, *33*, 515–527.

Udwin, O., & Yule, W. (1990). Expressive language of children with Williams syndrome. *American Jornal of Medical Genetics*, *Suppl. 6*, 109–114.

Ullman, M.T. (1993). *The computation of inflectional morphology.* Unpublished doctoral dissertation, Massachusetts Institute of Technology, Cambridge, MA.

Ullman, M.T., Corkin, S., Coppola, M., Hickok, G., Growdon, J.H., Koroshetz, W.J., & Pinker, S. (1997). A neural dissociation within language: Evidence that the mental dictionary is part of declarative memory, and that grammatical rules are processed by the procedural system. *Journal of Cognitive Neuroscience*, *9*, 266–276.

Ullman, M.T., & Gopnik, M. (1999). Inflectional morphology in a family with inherited specific language impairment. *Applied Psycholinguistics*, *20*, 51–117.

Van der Lely, H.K.J. (1997). Language and cognitive development in a grammatical SLI boy: Modularity and innateness. *Journal of Neurolinguistics*, *10*, 75–107.

Van der Lely, H.K.J. (1998). SLI in children: Movement, economy and deficits in the computational syntactic system. *Language Acquisition*, *7*, 161–192.

Van der Lely, H.K.J., & Stollwerck, L. (1996). A grammatical specific language impairment in children: An autosomal dominant inheritance? *Brain and Language*, *52*, 484–504.

Vicari, S., Brizzolara, D., Carlesimo, G., Pezzini, G., & Volterra, V. (1996). Memory abilities in children with Williams syndrome. *Cortex*, *32*, 503–514.

Vicari, S., Carlesimo, G., Brizzolara, D. & Pezzini, G. (1996). Short-term memory in children with Williams syndrome: A reduced contribution of lexical-semantic knowledge to word span. *Neuropsychologia*, *34*, 919–925.

Volterra, V., Capirci, O., Pezzini, G., Sabbadini, L., & Vicari, S. (1996). Linguistic abilities in Italian children with Williams syndrome. *Cortex*, *32*, 663–677.

Wechsler, D. (1992). *Wechsler Intelligence Scale for Children, 3rd Edition.* London: The Psychological Corporation.