Genetic Language Impairment: Unruly Grammars

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Summary. Though most children acquire language quickly and easily, some children have great difficulty in acquiring their native language. Over the past several years family studies and epidemiological studies have shown that this disorder aggregates in families. It has also been shown that monozygotic twins are significantly more concordant with respect to this disorder than dizygotic twins. This evidence suggests that at least some cases of this disorder may be heritable.

This paper will report on the linguistic properties of this disorder in English, Japanese and Greek. The cumulative data from several years of testing across several languages show that these subjects do not construct productive rules for such linguistic features as tense or case. They are able to use compensatory mechanisms such as conceptual selection, memorization and explicitly learned rules in place of automatic, procedural rules that normally govern language. These data suggest that this genetic disorder affects normal language learning mechanisms.

THE IDEA OF LANGUAGE AS AN INSTINCT

Darwin

CHARLES DARWIN thought that the ability to learn language was a special kind of instinct. '[Language] certainly is not a true instinct, for every language has to be learned. It differs, however, widely from all other arts, for man has an instinctive tendency to speak, as we see in the babble of our young children.' (Darwin, 1874). What we will show here is that this special 'instinct' can be impaired in some individuals. When it is impaired these children have to learn language without the help of their language instinct (Pinker 1994). They can learn by using other cognitive means, but the language that they construct shows characteristic differences from normal language.

Alternative models of language

Darwin's suggestion that language was founded on a biological instinct was lost for a while in a cloud of cultural relativism, which held that all languages (as well as all cultures) were radically different from one another, and behaviourism, which held that scientific explanations must not refer to non-observable entities like minds. The relativist viewpoint led linguists to concentrate on cataloguing the oddities that distinguished one language from another rather than the commonalties which they all shared. In fact Bloomfield specifically said that it would be inappropriate to postulate any universals of language: 'The only useful generalizations are inductive generalizations. Features which we think ought to be universal may be absent from the very next language that becomes accessible' (Bloomfield, 1933: 20). Linguists who adopted the behaviourist stance denied the existence of any such thing as 'mind' and they therefore did not believe in postulating any internalized abstract rules or representations.

Chomsky

Thirty-five years ago Chomsky challenged both relativism and behaviourism as explanations for language and revived the biological story. He said that the ability to acquire language is part of the biological endowment of human beings. He claimed that children come equipped with innate knowledge of the principles that are necessary for constructing human grammars. It is this set of universal principles which provides children with a blueprint for language learning. Children take this general plan and adapt it to fit the particular, specific properties of the language that they hear around them.

Chomsky as a linguist was able to provide empirically testable, specific proposals about the grammatical shape of the language instinct. There are several interrelated consequences to his proposal.

1. All languages built on same principles

If language is a consequence of an innate system then all human languages must be built on the same set of fundamental principles, despite their apparent surface differences. If there were a language that had a structure that violated these universal principles then minds like ours could not have produced it and would not be able to learn it. Linguists have investigated languages all over the world, from remote villages to busy cities, to see if this were true. These empirical studies have led to some revisions in the original proposals for the universal properties of language, but all in all it looks like there is a constrained set of principles that underlies all languages.

2. Modularity

The question is, 'How specific is this set of principles'. Chomskians argue that the principles that govern language design are much more specific than those that are used in general problem solving. They hold that the instinct to learn language is special and modular and is not merely a consequence of general intelligence (Fodor 1983). Others, like some connectionists, have argued that language learning is no different than any other kind of learning. They claim that learning language does not depend on a Universal Grammar, but rather on a Universal Learning Machine that can take anything as input and find the regularities within the system (Rumelhart & McClelland 1986). So far the jury is still out. The connectionists have built computer models that they claim 'learn language' using only general principles of inference. Linguists have shown that these models do not learn in the same way as children do, and besides there are properties of language that cannot be learned by these devices (Pinker & Prince 1988). The connectionists have changed their models to accommodate some of these objections, but some linguists still argue that there are properties of language that even the new connectionist models cannot account for. A more general problem with the connectionist models that have been proposed is whether they really reflect the way in which people think (Holyoak & Thagard 1995). Even if it can be shown that they are not merely interesting computational models, but are in fact accurate models of human cognition it is still an open question as to whether these models can, in principle, account for the complexities of human language. One of the crucial pieces of evidence that will help decide this is the empirical evidence

that we can gather from all aspects of language learning, including impairments that interfere with the normal acquisition of language.

3. *Acquisition*

Studies of the way in which children acquire language has shown that if there is any language around, spoken or signed, children seem to have an instinct that leads them to start building a grammar that follows the principles of language design. They instinctively know what to pay attention to in the language that they hear around them and what to ignore and what kinds of rules are likely to be language rules. For example, Kuhl has shown that when babies are only a few months old they can easily learn to discriminate between a man saying [a] and the same man saying [i] (Marean, *et al.* 1992). What is surprising is that with no further training the babies can make this discrimination when they hear a woman' s voice or a child's voice saying [a] or [i] even though these same sounds when said by a woman or a child have very different acoustic properties than when they are said by a man. The children appear to distinguish between those acoustic properties of sound that potentially signal linguistic meaning and those that characterize individual variations in voice quality. As children get older they are able to take the limited language that they have observed and infer recursive rules that allow them to produce not just the words and sentences that they have already heard, but a potentially infinite set of words and sentences that they have never heard before. Children do not always get it right the first time. The errors that they make tell us a lot about the rules they are using for grammar building. There are certain kinds of errors that they never make. For example, children learn that you can turn the sentence 'She is playing.' into a question by moving the verb 'is' to the front of the sentence 'Is she playing?'. But children do not try to turn the sentence 'The girl who is happy is playing.' into a question by moving the first 'is' to the front of the sentence. That would give you an ungrammatical sentence 'Is the girl who happy is playing?'. Children all over the world know that rules of language do not operate on the superficial properties of the linear string of words as they actually hear it. The rules that they construct, even the incorrect ones, operate on the hierarchical relations among the elements of the sentence.

Though we all automatically acquire and use these rules, we don't consciously know what they are. If we could bring them to consciousness, describing languages would be an easy task. Native speakers would just have to introspect and then write down the rules of their language. But even after hundreds of linguist-years of work we are still discovering new rules that govern languages.

4. Animal communication

The principles of human language design are radically different from the organizational principles of any animal communication system. Primates or other animals do not naturally develop a human-like language and cannot be explicitly taught the intricacies of such languages as the attempts to teach apes human-like language systems have shown (Terrace *et al.* 1979). It looks like human language is unrelated to any presently existing animal communication system. Some people have suggested that language is an epiphenomenon of the development of larger, more complex brains (Gould 1981; Lieberman 1992). Others argue that it evolved according to the basic principles of natural selection (Pinker & Bloom 1990). The origins of human language and its evolutionary history are still obscure. It may be the case that 'language' is not a single, unitary object that has a unified evolutionary history. It seems to be more likely that language is a complex system, that has been put together from parts that may have started out from very different beginnings and have followed different evolutionary paths.

5. Neurology

However it arose, it now seems to be the case that there are specified neural structures that subserve the instinct for language. Though the story is very complex, studies of developmental and acquired brain damage have provided evidence for the location and function of some of these structures.

   If language is part of the biological endowment of humans that has evolved since the line leading to man split off from those which lead to the other great apes then there must be some genetic properties of humans that build the particular kind of brain circuitry that is specialized for human language. Since the evolution of brain structure is connected with changes in the genes that guide the development of the brain it would not be surprising to find that some change in this genetic endowment can interfere with the way brain circuitry is laid down and thereby impair the ability to acquire or use language in the normal way. There has been some tentative new evidence that appears to indicate that there are anatomical anomalies in the brains of some individuals with language impairments: 'Magnetic resonance imaging scans of specifically language-impaired (SLI) boys were examined ... The distribution of perisylvian asymmetries in SLI subjects was significantly different from the distribution in controls ($P < 0.01$) ... These neuroanatomical findings suggest that a prenatal alteration of brain development underlies specific language impairment' (Plante *et al.* 1991: 52; Tallal *et al.* 1991).

Genetic language impairment

This paper will report on a natural experiment that impairs the ability to acquire language and therefore has the potential of giving us some insights into the nature of this genetic endowment. Our team thinks that there is some genetic factor (or factors) that interferes with the establishment of the neurological structures that subserve the acquisition of language. This, in turn, affects the ability to build the kinds of grammars that ordinary children build automatically and unconsciously.

Our work over the last ten years has shown that the language instinct can be impaired in very specific ways. In 1990 when I first reported that an inherited disorder could impair the ability to learn language (Gopnik 1990), the popular press (Associated Press, James Kilpatrick, *et al.*) credited me with having found a gene for grammar. For the record, though it might be nice if it were true, I have not discovered 'a grammar gene' nor do I think that there likely is a grammar gene. Even if there were a single gene that could impair the ability to learn language it would not follow that the good version of that gene would cause good grammar. Complex systems can go dramatically wrong if one small part is defective, as any user of computers knows all too well. Yet no one would say that the one small chip that made the whole system crash accounted for the normal functioning of the computer. Furthermore, if a gene (or genes) interferes with normal neurological development, as evidence seems to suggest, then it is likely that this same disorder may, in some individuals, impair other cognitive functions. It might even turn out that in certain circumstances, this same genetic factor might affect neurological development in areas of the brain that control other cognitive functions, while at the same time sparing the language centres altogether. These are speculative empirical questions, and they can only be resolved when the genes are found and their effects on neurological development are established.

The disorder

It is well established that some children have great difficulty in acquiring their own native language, even though they seem otherwise normal. Specific Language Impairment is defined as a developmental deficit of language in the absence of perceptual, motor, general cognitive, emotional or social problems (Bloom & Lahey 1978; Stark 1980; Wyke 1978; Zangwill 1978). This difficulty can persist into adulthood. Many investigators have reported that these subjects have particular difficulties with inflections such as tense (Miller 1981; Leonard *et al.* 1992; Clahsen 1989, 1992; Rice 1994; Gopnik 1994a; Ullman & Gopnik 1994). This is what we will report on here

in some detail: their problems with the linguistic rules that come under the rubric of 'morphology', that is those that mark tense, number, case etc.

Are we claiming that word formation is the only thing that is wrong with their grammar? Not at all. It is just what has been studied cross-linguistically in most detail. It has been documented that they also have difficulties in agreement within sentences, in constructing the rules for the sound system of English, and with more complex syntactic operations like relative clause formation. These other problems have been reported on elsewhere, by our team and others (Miller 1981; Leonard *et al.* 1992; Piggott & Robb 1994; van der Lely & Harris 1990; Bishop 1992, in press). These other problems appear to be consistent with what has been seen in morphology. They suggest that the impaired subjects build their grammars on different principles than normal children.

EVIDENCE FOR A GENETIC ETIOLOGY

There is converging data from epidemiological studies (Tallal *et al.* 1989; Tomblin 1989) and family studies (Samples & Lane 1985; Gopnik 1990; Hurst *et al.* 1990) that show that this disorder aggregates in families. The increased concordance in monozygotic, as compared to dizygotic, twins suggests that this disorder is likely to be heritable (Table 1).

These facts have geneticists all over the world searching for a genetic factor or factors that correlate with this inability to acquire language normally.

Alternative explanations

Several researchers have claimed that this disorder affects the grammar itself (Gopnik 1994a; Clahsen 1989; Rice 1994; van der Lely & Harris 1990) though they differ in the precise details of which particular part of grammar is affected. But not everyone wants to believe that grammar itself can be impaired. Some prefer to think that the problems that these subjects have with language are really caused by problems in the auditory input system (Tallal *et al.* 1980, 1991; Leonard 1989; Leonard *et al.* 1992) or in the

Table 1. Per cent of concordance in twin pairs with SLI.

Monozygotic	Dizygotic	Source
80	38	Tomblin & Buckwalter 1994
86	48	Lewis & Thompson 1992
89	48	Bishop *et al.*, in press.

articulatory output system (Fletcher 1990). Others, who doubt that the language faculty is modular, think that the disorder must be caused by some general problem with cognitive functioning (Johnston, in press; Bishop 1992).

These are empirical questions which are resolvable by carefully observing the facts about the natural history of this disorder. It is not enough to show that some of these subjects have articulatory problems, or that some others have auditory processing problems or that some have an assortment of other cognitive problems. The difficulty is that though some of the language impaired subjects have some of these additional problems, others do not have such problems. Furthermore, there are individuals with these other problems who do not have language problems. We know that many disorders can affect more than one system. As we have said above, if this disorder affects neurological development then it would not be surprising if it had broader effects than just language. However, the pattern of double dissociation between the language disorder and these other disorders suggests that in this case co-occurrence is not causation.

If we want to evaluate these alternative explanations then we must look at the specific predictions about what errors language impaired subjects will make that follow from each of these alternatives. Then we have to compare these predictions to the facts of just what these individuals can and cannot learn about language. Only then can we see which explanatory model best accounts for the full range of language facts that are actually observed. (It has been suggested that some non-linguistic factor may affect language development in complex ways that do not result in predictable consequences for language impairment. This, of course, may be the case, but such an explanation would not be testable at present.)

EVIDENCE FOR ABSTRACT GRAMMAR

One of the fundamental assumptions that all linguists make is that the words and sentences that a speaker produces are not simply chosen from a list of appropriate responses but are the product of an internalized system of rules that are capable of producing an infinite number of new sentences, most of which have never been uttered before. Though I have spoken about these issues before I have never used precisely the same set of sentences and you have never heard or read these sentences before. Yet the novelty of the actual utterances for me and for you does not in any way impede communication because we share the system of rules for English that allows us to encode and decode an infinite set of sentences. The same thing is true about words. We can and do make new ones up all the time. I can say:

> I was faxing two faxes but one turned out to be unfaxable. Even when I refaxed it they remained faxless. The problems gave me faxophobia so I just e-mailed it.

and though many of the words are new, both for me and for you, you do not have any trouble decoding the message. Therefore the empirically observable data can tell us much more than what sentences or words the speakers actually produce. These data can tell us about the system of rules, the grammar, that produced these responses.

Normal children do not acquire their language skills by mere imitation of what they hear or see around them but by creating a symbolic system of recursive rules that allows them to produce words and sentences that they have never heard before. Children who at 2 and a half say, 'I went to the store,' suddenly at three and a half start saying 'I goed to the store.' None of these children has ever heard the word 'goed' from their parents. So where does it come from? It appears that the child has gone from knowing the meanings of single words e.g. that the word 'went' means 'to move in the past' and that the word 'jumped' means 'to project oneself upward in the past', to knowing that there is a general rule for making past tense forms in English. In the flush of his new discovery the child, like many scientists with a new discovery, applies his new rule everywhere, even to words where it does not apply.

If we want to understand what is going on in either normal or impaired subjects then we must use the observable data as evidence for what is going on in their grammar. This gets complicated because the very concept of observable linguistic data is problematic. Two speakers can produce identical surface forms e.g. 'jumped' and they may be derived by two very different routes from two very different grammars, just as two Turing machines may both produce similar outputs even when they have very different internal rules. The only way you can tell if two forms are the same or different is to see how they fit into all of the other evidence about the system of rules that the subject is using. And that is what we will do here. We will present converging evidence from several different observations that show that language impaired subjects build grammars that are very different in kind than those built by unimpaired speakers and that the same kind of aberrant grammars are built by language impaired subjects in English, in Greek and in Japanese. These three languages have different grammars. By comparing data across these three languages we can determine which problems are the result of the peculiarities of one language and which problems are more general.

These data show that these subjects do not construct unconscious abstract rules for forming words, a skill that four year olds perform automatically. They can learn to compensate for this inability by

memorizing complex words like 'walked' in the same way that unimpaired speakers have to memorize an irregular form like 'went'. They can also learn to use conscious explicit rules, which are routinely taught to them in speech therapy, as an imperfect surrogate for the unconscious, implicit rules that are used by unimpaired speakers. Though they have problems under-standing the role of grammatical rules for conveying meanings such as 'past', they can rely on the semantic meanings of words and sentences to communicate these concepts effectively (Paradis & Gopnik 1994; Ullman & Gopnik 1994).

We can show that these aberrant grammars cannot be explained in terms of an impairment in auditory perception, articulation or general intelligence. As we have said, some people believe that the ability of children to make these generalizations about language is just a consequence of their general intelligence. Others, following Chomsky, believe that the ability to learn language is not connected to general intelligence, but is the consequence of a specific innate ability that is independent of general intelligence. The evidence from this developmental disorder of language is relevant to this debate. If individuals who have normal intelligence can lose the ability to construct normal grammars then this supports the idea that grammars and general intelligence are independent. On the other hand, if this develop-mental disorder of language can be shown to be a direct consequence of an impairment in general intelligence then perhaps language is not modular after all.

Evidence

It is widely reported by speech pathologists that this language disorder occurs in children who have very high non-verbal IQ scores, as high as 140. It is also the case, as one would expect if IQ and language impairment were not correlated, that some of the individuals with language impairment have low non-verbal IQ scores. Bishop has reported that monozygotic twins who have similar impairments of language sometimes have quite different non-verbal IQ scores (Bishop, in press a). Our data agree. In a set of monozygotic language impaired twelve year old twins the twin with the more serious language impairment had a higher non-verbal IQ than his brother (PIQ 91 vs. 86, WISC-III). Among the many subjects that we have studied are the members in a large family (Figure 1) in which the pattern of the disorder is indicative of an autosomal dominant gene (Pembrey 1992).

In 1990 Hurst *et al.* reported that the IQs of the members of this family were within the normal range (Hurst *et al.* 1990). Pembrey, reporting on the same family said: 'Using the WAIS-R/WISC-R scales, the mean perfor-mance IQ of these 13 affected members is 95 (80–112)' (Pembrey 1992: 54).
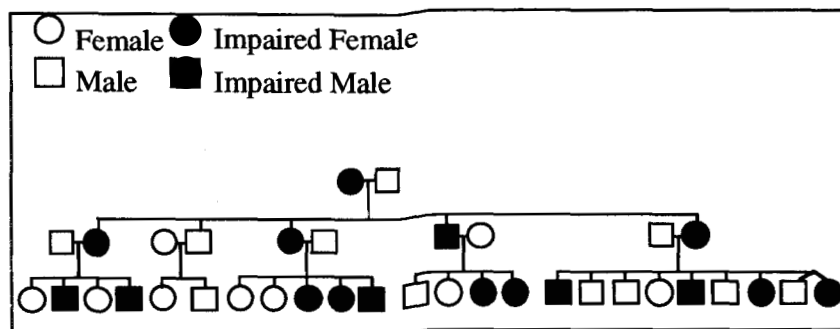
Figure 1. Family tree of affected family

We did not test the IQ scores of these subjects independently, but we cited Hurst and Pembrey's reports in our work and pointed out that in addition to the subjects they reported on, one of the other members of the family in the middle generation was known to have been in a special school for slow learners and as an adult had great difficulty with reading or doing arithmetic which suggested that she had a low performance IQ. Two years later members of the Pembrey research team reported that subjects in this family had '… a mean performance IQ of 86 (range 71–111) (compare the unaffected members' mean score of 104 (range 84–119))' (Vargha-Khadem *et al.* 1995: 932). In that recent report they do not mention their earlier report. Part of the change is the result of a general revision of the IQ norms that lowered all scores by 4–8 points. The inclusion in this group of the cognitively impaired subject referred to above probably accounts for a portion of the rest of the difference. However, even if the reported means for the affected and unaffected members of the family are different, the IQ scores of the language impaired subjects and their unimpaired relatives overlap substantially. One clearly language impaired subject has a non-verbal IQ of 111, while an unimpaired relative has a non-verbal IQ of 84, almost 30 points lower. Though the IQ scores of the language impaired members of this family are reported to vary widely, they all seem to have similar problems with language, though the severity varies. The impaired Japanese and Greek speakers, who show the same pattern of language deficits, have the same range of performance IQ scores (Japanese, 81–103; Greek, 86–111). So there is no reason to believe that the language disorder in this family is *caused* by a cognitive deficit. On the other hand, if they cannot use their normal instinct for acquiring language and therefore have to use other cognitive skills to learn language then the ones who have better cognitive skills should be better at, for example, learning explicit rules. Therefore while an impairment in intelligence might not *cause* the language

disorder it might affect the ability to use various strategies to compensate for the deficit. So you can see that individuals with language impairment run the whole gamut of intelligence, from very bright to not bright at all. And vice-versa. People who have normal language come in all ranges of intelligence. Some people who don't have the cognitive skills to manage simple tasks in the world have fluent, grammatical language. What they say may not be true or make any sense, but their language follows the rules of grammar (Bellugi *et al.* 1991; Smith *et al.* 1994). It looks like general intelligence and the ability to build grammars of a particular kind are independent.

Auditory/articulatory accounts

Could the problems that these people have with language be a result of not being able to process sounds efficiently or not being able to pronounce words accurately? (Tallal *et al.* 1980, 1991; Leonard 1989; Leonard *et al.* 1992; Fletcher 1990.) If that were true then nothing would be wrong with their language ability, only with their input or output systems. At first blush such an explanation might appear to be plausible. Some people with this disorder have difficulty in processing transient auditory signals; other subjects have been shown to have difficulties with sequencing oral-facial movements. So some, though not all, of these language impaired subjects have auditory or articulatory problems. On the language side one of the recurrent problems that is reported is that these subjects have problems with past tense and plural in English. If someone says: 'Last week I jump over the fence,' instead of 'jumped' it could be because they did not process the -ed sound because it went by too quickly and was therefore difficult to process, or because it took too much co-ordination to pronounce.

But when they say 'Two weeks ago I go,' instead of 'went' or 'He did it then he fall,' instead of 'fell', then these anti-grammatical explanations are in trouble. No one could suppose that mistaking 'go' for 'went' or 'fall' for 'fell' can be explained by an auditory or articulatory problem. Furthermore, when these subjects use these same sounds in simple words where they are not being used to signal past, e.g. car/card (similar to mar/marred); ball/bell (similar to fall/fell) they can produce and perceive these sounds quite accurately (Leonard *et al.* 1992; Goad & Gopnik 1994; Gopnik 1994b). There are many similar examples from Japanese and Greek. For example, in Japanese they have difficulties with 'probable-future' marking even though it is encoded by a separate word *deshoo*. The passive is encoded by a two syllable morpheme, *rare*, that occurs in the middle of the word and yet the Japanese subjects omit it and use the past form of eat, *tabeta* (ate) when they should use the past passive *taberareta* (was eaten). In Greek they substitute one complex inflected form for another even though the forms are distinct

and they sometimes omit the whole verb. They say:

dhe thelo	*	ki ... kimi ...	dhe *kimame
NEG want-I	missing	sl ... sle ...	NEG sleep-I
	compl.	non-continuous verb root only rephrasal (missing affix)	continuous root + affix

?*Maria   kato   parea.
(Maria downstairs together.)

when they should say:

Maria   pame   kato   parea.
(Maria   lets-go   downstairs   together.)

They also appear to have trouble with larger syntactic structures like relative clauses which would be hard to account for by any auditory or articulatory deficit.

Table 2. Examples of SLI affixation in Japanese and Greek.

	Japanese	Greek
they say:	tabe-ta (ate)	Maria kato parea (M. downstairs together)
they mean:	tabe-rare-ta (was eaten)	M. pame kato parea (M. lets-go downstairs together)

And they don't have trouble just with producing the correct forms. They have the same problems across the board, in judging sentences to be grammatically correct and in correcting grammatical errors (Table 3). They have the same problems when they hear the sentences or when they read them; in spontaneous speech and in spontaneous letter writing; when they have to respond to a test with a sentence, or with a word, or with a rating number or with 'yes' or 'no'. No matter what the form of the input or output they make the same grammatical mistakes (Matthews 1994). So while a small part of the data might be consistent with an auditory or articulatory problem, there is an overwhelming amount of other data that cannot be explained by either mishearing or misspeaking.

Table 3. Grammaticality judgements of SLI in English, Japanese, and Greek.

	English	Japanese	Greek
Judgement of grammatical errors	57%	43%	34%
Appropriate error corrections	37%	35%	17.2%

Our hypothesis

Evidence for the absence of abstract rules, novels

I made a strong claim before that these subjects cannot construct abstract inflectional rules that allow them to generate, for example, past tense and plural forms. There are two ways that past and plural forms arise. Irregular past forms must be memorized and listed in the lexicon separately from the present form because they are not predictable from the present form. All forms that are not irregular are produced by taking the root form of the word and applying the regular rule (Pinker 1991). These are the kinds of rules that every four year old automatically and unconsciously constructs. Young children know that the regular rule applies equally to existing and novel words. If someone is using a rule to produce the inflected forms then they should be able to apply this rule to novel forms. If, on the other hand, the inflected forms are being stored lexically, that is as separate words in a mental dictionary, then the subjects should have problems with inflecting novel forms. Some investigators (Leonard 1989; Leonard *et al.* 1992; Rice & Oetting 1993; Rice 1994; Bishop, in press b) have argued that the impaired subjects must have these rules because they produce inflected forms like 'walked' in spontaneous speech and in tests. However, even if the subjects produce the right inflected form of an existing word, in spontaneous speech or in test situations, we really cannot tell if they have the rule or if they have simply memorized the word as a whole. The word 'books' could either be generated by rule from the root 'book' and the rule for pluralization or it could be listed in the lexicon as 'books' with the meaning of 'several objects for reading'. But if they know the rule they should be able to apply it to novel words that they have never heard before. The ability to inflect novel forms provides us with an empirical test that can distinguish between a form being retrieved from the lexicon and that same form being generated by a productive rule. We tried several different tests which required the subjects to inflect novel forms in English, Japanese and Greek. The subjects were given novel roots, like 'wug', and then were given a semantic context that required the inflected form of the word. Sometimes this was done by
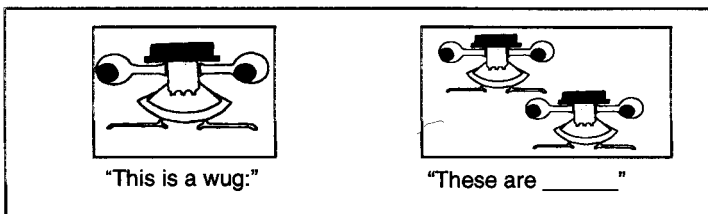

Figure 2. Sample 'wug' stimuli.

Table 4. Production of inflected novel forms: accuracy of SLI and control populations.

Language	(Morphological operation)	Controls	Impaired
English	Past Tense	95.4%	27.0%
	Plurals	94.9%	9.0%*
Japanese	Past Tense	89.0%	37.0%
	Rendaku†	80.5%	22.1%
Greek	Plurals	78.8%	42.1%
	Compounds	93.6%	12.8%

* After close phonetic analysis.
† *Rendaku*, 'sequential voicing', is a highly productive morphophonological operation in Japanese compound formation. Word initial voiceless obstruents of the second compound member become voiced in the process of compounding.

showing them pictures of imaginary objects (Figure 2). In other cases the context was established within the sentence:

Everyday I crog to John.
Just like everyday, yesterday I _____ to John.

In every one of these tests the language impaired subjects did significantly worse than the controls (Table 4). The data across all three languages shows that the language impaired subjects cannot reliably inflect words that they have never encountered while the controls are able to do so.

The lexical listing hypothesis

These data show that they cannot productively use rules to construct novel inflected words or novel compounds. We still have to account for the fact that they sometimes do produce words that have the same surface form as inflected words. If we want to maintain that they do not have inflectional rules what we need to show is that the words that they produce do not have any internal morphological structure though these same words are represented as a root plus an inflectional ending in the grammars of non-impaired subjects. We have looked at three independent sources of data to test the hypothesis that words that are inflected in the normal grammar are treated by language impaired subjects as unanalysed lexical words: (1) the ability to extract roots from inflected words; (2) on-line processing of inflected and uninflected forms; and (3) frequency effects.

Access to roots

The most direct kind of evidence that can tell us if the impaired subjects know the internal structure of words is their ability to access this internal

structure and use these parts in constructing new words. English is not a particularly good language to investigate this hypothesis because words in English can occur without any overt inflections. For example the root underlying 'walks', 'walking' and 'walked' is 'walk'. Unfortunately this root is identical to the first person, singular present form 'walk' which occurs without any overt inflectional marker. Therefore if the subject produces the form 'walk' it is impossible to know if it comes from an analysis of the internal structure of inflected words or is simply the word 'walk'. Greek provides an ideal test case. All nouns in Greek are inflected. For example, the word for 'wolf' has eight different inflected forms.

The root for 'wolf', *lik-*, never occurs by itself in Greek (Table 5). So Greek children never hear the root *lik-* by itself. In order to discover the root of the word they must be able to abstract the root from all of the inflected forms for 'wolf' that they hear. If they can do this then they must be treating these words as made up of a root and an inflection. On the other hand, if they treat each of these forms of 'wolf' as a separate uninflected simple word, then they should not be able to extract the root. One linguistic context which can test for the subjects knowledge of roots is compounding in Greek. Compound words like 'wolfman' are made by concatenating the root for 'wolf', *lik-*, with the root for 'man', *anthrop-*, and then attaching the inflection to the end of the compound stem. This means that the first element of a compound is always a bare root (the second element has the surface form of an inflected word since the inflection for the whole word is attached to the end of the compound). In order to produce a compound correctly the speaker must abstract the bare root form of the first element of the compound from the inflected forms that he has heard. If a speaker can reliably produce the root in a compound then it is reasonable to conclude that the speaker is treating the inflectional forms as if they were made up of a root plus an inflection. On the other hand if they cannot reliably find the roots then it is reasonable to suspect that they do not represent words in Greek as being composed of roots and inflections.

There is one other property of Greek compounding that allows us to investigate the speakers understanding of the internal structure of words. If the second element of a compound noun begins with a consonant then an *o*

Table 5.   Full declension of a Greek noun.

	Singular	Plural
Nominative	lik os	lik i
Genitive	lik u	lik on
Accusative	lik o	lik us
Vocative	lik e(!)	lik i

Na énas líkos.
(Here is a wolf)

Na énas anthropos pu... "**likanthropos**"
(Here is a man who becomes a wolf. We call him...)

Na énas pondikós.
(Here is a mouse)

Na énas anthropos pu..."**pondikanthropos**"
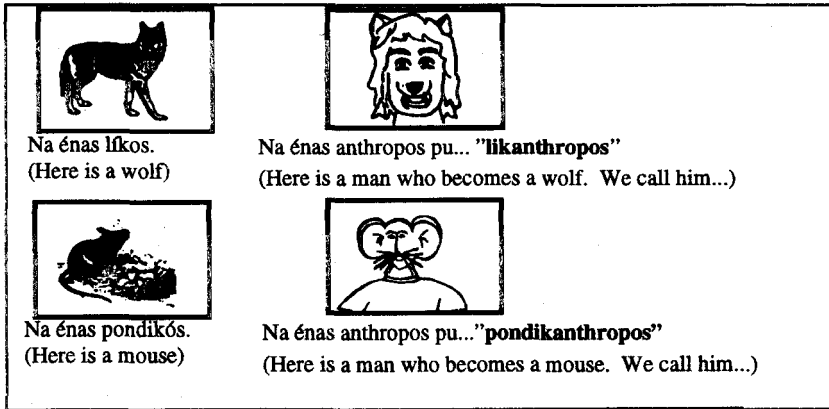(Here is a man who becomes a mouse. We call him...)

Figure 3. Sample stimuli from Greek compounding task.

is inserted between the two roots. In order to use this rule correctly the speaker must know two different things; first of all the speaker must know where the boundary between the two roots is in order to insert the *o* in the correct location, and secondly must know that the *o* is only inserted before second roots that begin with a consonant.

So compounds in Greek give us two different diagnostic tests of whether language impaired subjects are aware of root boundaries and inflections. To produce a compound they must be able to extract the root for the first element from the inflected words that contain this root. If they choose to insert an *o* in the compound they must insert it at the boundary between the two roots. The knowledge of which compounds require an *o* and which do not, is independent of the speakers knowledge of root boundaries. A speaker could mistakenly believe that a compound requires an *o* when it does not, but still insert the *o* between the two roots, as is the case with younger non-impaired Greek children. In this case the compound is incorrect, but the subject still demonstrates knowledge of the root boundary. The over-generalization of the *o* in Greek compounds in this case is similar to the overgeneralization of the regular past marker to irregular verbs in English, 'goed' for 'went'.

It should be the case that if the word already exists in the language, like 'wolfman' [Greek: *likanthropos*], the impaired subjects may be able to produce it because they could have it listed as a whole word, though most of these words are infrequent. But if they are asked to produce a novel word like 'mouseman' [Greek: *pondikanthropos*] they should have great difficulty because they will not know how to find the root for 'mouse'. The subjects were visually and aurally presented with the stimuli in Figure 3 and asked to produce novel compounds.

Table 6. Greek error rates.

Error type	FLI subjects	Young controls	Age-matched controls
Sum of Root Errors	83.9%	5.0%	1.25%
Incorrect -*o* Realization	3.8%	79.0%	12.0%
Total Errors	66.4%	29.3%	1.5%

And that is exactly what happens (Table 6). The impaired subjects are very bad at knowing where the root boundary is. Sometimes they produce a form that is shorter than the real root (like /anthrofàghos/ instead of /anthropofàghos/ for 'maneater') and other times they produce a form that is longer than the real root (/hinothanthropos/ instead of /hinanthropos/ for 'gooseman'). The impaired subjects use *o* significantly less frequently than non-impaired subjects and do not seem to overgeneralize its use. Moreover, when the impaired subjects try to use the *o* that signals the boundary between the two roots they often insert it in positions that are not true root boundaries. In contrast, the younger controls respect root boundaries even though they often overgeneralize the *o* insertion rule and insert an *o* in contexts in which it is not required. For example the young controls produce forms like /pondikoanthropos/ when they should say /pondikanthropos/. They seem to have an *o* insertion rule that marks compounding, but they have not yet learned the constraints on this rule. This tendency of young children to overgeneralize a rule that they have recently learned is a typical property of normal language acquisition. The age-matched controls make virtually no errors at all. They can extract the roots and they know the constraints on the compounding rule.

These data show that the unimpaired children, young and old, know that nouns have a complex internal structure made up of a root and an inflection. The impaired subjects do not appear to recognize that inflected words have this complex internal structure.

Though these native Greek children with language impairment do not appear to acquire the rule for *o* insertion in Greek compounds, you and I, native speakers of English, have unconsciously internalized this Greek rule. Earlier in this paper, in the example about faxes, the word *faxophobia* was used to illustrate the productivity of word formation rules. Native speakers of English judge *faxophobia* to be a natural new coinage and they prefer it to *faxphobia*. What is odd is that the *o* in *faxophobia* follows from the Greek rule for compounding not the English rule. It appears that native speakers of English, on the basis of a few examples from Greek like *claustrophobia* and *acrophobia*, unconsciously construct the Greek *o* insertion rule. This simple, natural ability is what appears to be missing in these children with language impairment.

On-line tests

Another method to see if they process inflected forms differently from uninflected ones is to use on-line lexical decision tasks. These tasks are implicit methods used to tap the underlying mental representations. Kehayia (1994) reports on two different on-line experiments; a simple lexical decision task and a morphological priming task in which the target stimulus was primed by another related or unrelated word. There were five English speaking language impaired subjects and 25 English speaking non-impaired subjects. These tasks measure the amount of time (in milliseconds, ms) it takes for the subject to make that decision and permit us to study the patterns of word recognition and lexical access adopted by the subjects. Finally, these patterns can provide us with valuable insight concerning the organization of underlying representations in the mental lexicon.

In the simple lexical decision task, which we will discuss here briefly, subjects are asked to decide whether a sequence of letters presented to them on a computer screen is a real word of the language. They are told to press a key marked 'yes' if the stimulus is a real word or a key marked 'no' if it is not and to respond as fast as they can, while still being accurate. There were four different kinds of experimental stimuli: uninflected real verbs like 'walk', inflected real verbs, like 'walked', uninflected novel words like 'zash', and inflected novel words like 'zashed'. The stimulus set also included filler and control words to reduce density. The results show that neither the impaired nor control subjects had any difficulty distinguishing between real words and novel words, though both the impaired and the control subjects take longer to process novel words than existing words. However, within these two classes their patterns of word recognition were quite different. Controls, in this experiment and in other similar experiments (e.g.: Kehayia 1993; Kehayia & Jarema 1994) take significantly longer (more than 30 ms, $P < 0.001$) to process the inflected form of the word than to process the uninflected form of the word, i.e. it takes them longer to decide that 'walked' is a word than that 'walk' is a word, or that 'zashed' is not a word than it takes them to decide that 'zash' is not a word (Table 7). These sorts of data have been interpreted to indicate that subjects are sensitive to the presence

Table 7. Lexical decision times (milliseconds) for impaired and controls.

	Impaired	Controls
Non-words (Root)	925 ms	620 ms
Non-words (Inflected)	910 ms	652 ms
Words (Root)	792 ms	450 ms
Words (Inflected)	809 ms	480 ms

of the inflection on either a real or a novel word and that the presence of the inflection requires the speaker to perform some additional processing step. Impaired subjects, on the other hand, were faster, although not significantly, when recognizing inflected novel words, unlike their control counterparts who showed the reverse pattern. With respect to the impaired subjects' recognition of inflected real words even though they appear to take 17 ms longer than when recognizing simple words, this difference is neither significant nor constant across the five subjects. Furthermore results from the priming experiment show a non-differential treatment of inflected and uninflected verbs contrary to results obtained for the control subjects. Findings from this latter experiment also show minimal to non-existent effects of morphological relatedness even in cases of complete root transparency (e.g. wash-washed), unlike findings from the control group that yield strong effects of morphological relatedness (e.g. Stanners *et al.* 1979; Napps 1989; Kehayia 1993; Kehayia & Jarema 1994). Thus, the above results indicate that the language impaired subjects appear to be insensitive to the presence of the inflection when they process words in simple or in primed conditions. Inflected words seem to be recognized as chunks with no processing or decomposition of the inflectional suffix.

Given these results and the possible unavailability of a productive morphological rule for the marking of past tense as has already been suggested, the decomposition of verbs inflected for the past would be impossible. It is thus proposed that the mental lexicon of these subjects contains a full list of all simple and complex lexical items with no internal word structure representation for complex words. Such a proposal would account for the occasional production of past tensed verbs in spontaneous speech or during testing.

The unavailability of rules is further evidenced in the results from four impaired Greek-speaking SLI children tested on real and novel compounds in Greek, using an on-line simple lexical decision task. Their performance was compared to that of 10 normal controls. The overall results show similar recognition patterns for the impaired as those reported in the previous study. The most striking result concerns the unavailability of the compounding rule which led to the swift rejection of novel compounds even though controls appeared to either accept them or reject them with great delays.

Frequency

One way of finding out if the word is generated or is listed in the lexicon is to see if there are any frequency effects. If a word is listed in the lexicon then its frequency should affect whether or not it is retrieved. If, on the other hand,

Table 8. Effect of frequency on morphological production in Japanese.

Task		Frequent	Non-frequent
Rendaku	Impaired	88.8%	33.3%
	Control	94.5% (n.s.)	94.5% ($P = 0.001$)
Past tense	Impaired	73%	68%
(Nas/V)	Control	96% ($P = 0.055$)	97.5% ($P = 0.02$)

it is derived from a rule, then there should be no frequency effect. We know this is true for normals who show frequency effects for irregular verbs, but not for regulars. We looked at the performance of the impaired subjects on existing regular forms. As predicted by the lexical listing hypothesis the likelihood of their producing an existing regular past tense verb in English was dependent on the frequency of the existing past tense form. In Japanese the impaired subjects were much better at voicing existing compounds and inflecting verbs that were judged to be frequent than those which were judged to be infrequent; there was no such effect for the controls (Table 8).

The Greek compounding data, the on-line data and the frequency data all tell the same story; the impaired subjects do not treat inflected words as if they were composed of constituent parts. So it seems reasonable to say that when these subjects produce a word like 'cats', which may look as if is inflected, we cannot assume that this word is composed of a root plus an affix in their mental grammar.

Implicit vs. explicit rules

One of the interesting differences between the impaired and unimpaired subjects is that the unimpaired subjects, even very young ones, acquire the rules of their language unconsciously and with no explicit training. The impaired subjects, even when they have had speech therapy for years that attempts to teach them the rules, never internalize the complex constraints that underlie these rules. They can learn the simple version of the rules, like 'add an -s', but they are oblivious to the wonderful intricacies of language that come for free with the language instinct. The evidence suggests that while the impaired subjects are not able to construct implicit, automatic inflectional rules, some of them are able, on some occasions, to apply explicit rules (Paradis & Gopnik 1994).

There are several empirical differences between the responses from explicit and implicit rules that allow us to distinguish between them. One way is to see if the subject's responses reflect the full complexity of the inflectional rule or if they reflect a much more simplified explicit rule. For

Table 9. Phonological rules for English pluralization.

Singular	Plural	Rule
cat	cats /kæts/	add an /s/ after unvoiced obstruents
dog	dogz /dogz/	add a /z/ after voiced obstruents
bus	buses /mæsiz/	add /Iz/ after sibliants

example, the rule for plurals and pasts in English looks simple. There is a small set of irregular forms that have to be memorized e.g. man/men, go/went. All of the other nouns or verbs in English follow the regular rule. Every English speaker automatically obeys these rules, but very few can describe their workings because they are part of their implicit knowledge. Everybody would say that we add an *-s* to a noun to make the plural, and that we add an *-ed* to a verb to make the past, but there is a lot more to it than that (Table 9).

The ending has to agree in voicing with the final sound of the root, *cats* (cats) vs. *dogz* (dogs); *jumpt* (jumped) vs. *jogd* (jogged). If the root ends with a sound that is like the sound of the inflection then you have to insert a vowel, *buses* not *buss*; *loaded* not *loadd*. And there is no stress on the inflectional ending, *buses* not *busES*; *loaded* not *loadED*. This might seem complex for a four year old, but children have help. They do not have to figure out that there is voicing agreement when the root ends in an obstruent like *t* or *g*, or that the inflectional ending is virtually never stressed or that it would be extremely unusual for a language to allow two like sounds together at the end of a word or that the regular rule applies to any word that is not marked as irregular. These are fundamental, widespread properties of language and the child's first guess is that a human grammar should be built like this. Given this advantage it is not hard for children to automatically and implicitly construct the rule for plural with all of its complexities before they are four years old.

The evidence from the performance of these subjects on novel verbs indicates that they do not have the regular rule in English for past or for plural. But they sometimes are able to produce a seemingly inflected form for a novel word and, on occasion, in spontaneous speech they produce overregularizations like *eated*. These data have been used to argue that they have the rule, but just are unable to produce it on all appropriate occasions. A careful phonetic examination of the forms that they produce tells a different story. Some of the impaired adults looked like they were producing

Table 10. A metalinguistic response from a 45-year-old
SLI woman.

Stimuli	Produced form	Correct form
vub	/vub-s/	/vub-z/
fen	/fen-s/	/fen-z/
tuss	/tuss-s/	/tuss-iz/
praz	/praz-es/	/præz-iz/

some of the novel plurals and novel pasts correctly. But when you looked
closer at the phonetic shape of their attempts it was clear that they were not
using the rule used by all four year olds. They were using a much simpler
rule that did not have any of the normal constraints.

One 45-year-old who was shown a picture of a crab and given the
English word *crab* responded with:

> Crab-S [with an incorrect *s* sound instead of the appropriate *z* sound] you have
> to put a *s* to it. All the time.

She correctly used the rule that she articulated, but unfortunately it is not
the correct rule. She violated the necessary constraints that we discussed
above and made precisely those errors that young children do not make. She
added an *s* to novel words that ended in a voiced obstruent and produced
vub-s as the plural of *vub*. She added an *s* directly to words that ended in a
sibilant and gave *tuss* as the plural of *tus*. And she put a second stress on
the ending and gave *praz-ES* as the plural of *praz* (Table 10). This pattern of
providing metalinguistic statements about the rules that they are using and
producing errors that show that they are using simple, explicit rules is
characteristic of several of the impaired subjects in both the plural and past
tense production tasks (Goad & Rebellati 1994; Ullman & Gopnik 1994;
Gopnik 1994a). These data indicate that the impaired are not really treating
these endings as inflections which are incorporated into the root. The
phonetic shape of their productions violates fundamental constraints of
English. What they are doing is using an explicit rule to take a word-like
element, *s*, which means 'more than one' and simply concatenating it with
the root.

SUMMARY

Our observations across three different languages from a wide range of
different tests and from naturally occurring language all point in the same
direction; that the language impaired subjects do not represent words as

Table 11. Genetic Language Impairment team.

J. Brostoff (R.A.)	E. Kehayia (processing)
J. Dalalakis (Greek)	M. Kessler Robb (phonology)
S. Fukuda (Japanese)	R. Palmour (genetics)
S. E. Fukuda (Japanese)	M. Paradis (neurolinguistics)
H. Goad (plural test)	G. Piggott (phonology)
M. Joanisse (R.A.)	C. Rebellati (plural test)
M. Ullman (past test)	

composed of roots and inflections and they do not construct the same kinds of rules and grammars as normal children do. (There is also evidence, that we do not have time to discuss here, that this cluster of symptoms is neurologically plausible.)

And now we are extending our study to see if we can find out just exactly what the genetic and neurological consequences of this disorder are. We now have a new team that is working on this larger study (Table 11).

It appears that Darwin was right. There is a language instinct. It guides children to pay special attention to the language around them and it tells them how to build a grammar. When it goes wrong they never can just automatically acquire language. They can, with hard work, learn to simulate language behaviour.

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