A Program for the Genetics of Grammar

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Departing from Lenneberg's biological conception of language and its development, this paper first reviews select examples from research on language development and its interface with genetics before making some specific proposals with regard to how the genetics of grammar could be investigated. The central proposal of this paper is that an important, perhaps necessary, avenue for studying the genetics of grammar is to study the genotypes corresponding to phenotypes of child (and genetically impaired) versions of the computational system of grammar, as opposed to strictly descriptive measures of a construction or standardized linguistic tests. In some cases, these phenotypes have wide explanatory ability, suggesting that they directly involve parts of the computational system of language. The primary example discussed is the phenotype of the Unique Checking Constraint (UCC). In particular, it is proposed that one could usefully start to investigate the genetic basis for he development of finiteness, object clitic omission, and related phenomena of the UCC. A second, less developed example here, corresponding to a much later developmental stage, is the Universal Phase Requirement (UPR), regulating verbal passives and many other phenomena in children.

Keywords: genetics; biolinguistics; syntax; language acquisition; Unique Checking Constraint (UCC); Universal Phase Requirement (UPR)

1. Introduction

Eric Lenneberg (1967) proposed a view of human language that situated language and its development (a particular interest of Lenneberg's, for good reason, given his overall view of language) squarely within a classical biological framework that saw at least some parts of human knowledge as being rooted in human biology. His view was very much different from the standard psychological framework that assumes learned "associations" as the fundamental basis for language. For him, language was species-specific and resulted from human biology. We might think of the capacity for sonar in bats as a comparable example. Whatever learning takes place in the bat, there is no question but that the bat is equipped for sonar by its biology. The contemporary view of human language (as in a major classical tradition) treats it in the same way, as Lenneberg saw that it should.

I would like to thank two anonymous reviewers, who made excellent suggestions, some of which I have responded to extensively. I also thank the editor, Patrick Trettenbrein, for suggesting that I write a paper and for showing a great deal of enthusiasm and patience as I worked through this. It goes without saying that all the errors are my own.

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One might speculate that the case of sonar is different because sonar is a sensory ability, rather than a deeper cognitive ability. I fail to see any argument for this position. Bat sonar is put to both perceptual (not purely sensory in any kind of sense that can be made of "sensory") and productive uses (as when the bat uses sonar to navigate). In this way it is like language, which is used to both comprehend and speak (or produce with other means, as in sign language). Sonar is a computational system in which the bat uses particular kinds of physical observations to compute information about properties like where objects are. This information can be used in navigation. We do not know if this is conscious computation, but given the unconscious nature of most of human linguistic computation (and other kinds of cognitive and perceptual computation), it would seem quite plausible that it is mostly, perhaps completely, unconscious. This very natural view should be extended to language: Why should we, as biological creatures, escape how biology works in general?

Lenneberg paid much attention to linguistic development as part of his argument. At the time, not too much was known about the details of the development (often called acquisition) of syntactic and semantic systems. But the simple properties that were known (the one-word stage, etc.) were enough to make Lenneberg see this development as consistent with the biological view. In the last 50 years, there has been extensive progress in results on the development of syntax and semantics, progress that allows us to strongly confirm the biological view of language. Linguistic development is a central part of the contemporary biolinguistic view, with some of its strongest results (outside of linguistic theory itself).

Can we go beyond this study and this basic claim about development and the biology of language? Can we in fact create a genetics of language and a developmental biology of language with a detailed analysis of the physical mechanisms that underlie the development of the computational system of language? The purpose of this paper is to argue that the progress that has been made in the study of language acquisition can yield the appropriate statement of the nature of the developmental phenotype that provides a natural set of hypotheses about what should be tied together (and not) in the development of language. In turn, these correlations and patterns should provide material that allows for the detailed development of a genetics and developmental biology of language. We will make some suggestions about which parts of the developmental phenotype are promising as an aid to the development of the biology. The phenotypical studies are a necessary first step. I would suggest that the results already achieved in the phenotypical studies in language acquisition are promising enough that it is worth exploring these from the detailed biological point of view.

2. Why Genetics Matters: Unification and Discovery

Unification is one of the strongest goals in science, and a strong feature of the most successful sciences. We feel that we have understood more if we have a more unified theory. Unification is strongly related to the notion of simplicity. A unified theory has principles that correctly cover a wide range of empirical phenomena. Sometimes what appear to be different levels of explanation can be unified. This results in an even stronger theory, covering a wider range of phenomena. Moreover,

this unification can lead to understanding the particular levels in deeper ways than were previously understood.

Modern linguistic theory provides ample illustrations for such a move toward unification. In fact, unification may even be its most distinctive feature. It has been a constant tool of Chomsky's, since the beginning of generative work (Chomsky 2005). We are no longer satisfied with descriptions of particular constructions as an adequate theory. We want to know what the underlying grammatical computations are, the ones that result in particular constructions.

Moreover, Chomsky unified the study of linguistic description (understanding the different languages of the world) with the problem of language acquisition: the child's choice of which language she is encountering in her environment. Chomsky called this unification the problem of *explanatory adequacy*. We sometimes also refer to it as the *learnability* problem. There can be no question that focusing on this problem not only helped us to understand how language acquisition proceeds, but also had a major impact on the development of particular linguistic theories.

The contemporary science of language acquisition (i.e. linguistic development) has unified its theorizing and experimenting with the results of work coming from linguistic theory. Although it is widely known and accepted that the goal of explanatory adequacy has helped us establish the correct descriptions of linguistic phenomena, perhaps it is less widely known that the pursuit of the same types of unification has moved the study of language acquisition considerably beyond its pre-generative state. In the study of linguistic development, we are no longer content with descriptions of particular surface phenomena in a child's language at particular times, taking account of the particular language that the child is encountering. Rather, we look for the underlying principles of the grammar that are developing, unifying with linguistic theory. We do not look for the development of particular constructions. Rather, in my opinion, the major advances in the pursuit of language acquisition in the last 25 years are due to the pursuit of the same type of unification in theorizing that has characterized linguistic theory and other successful sciences.

To take an example that we will flesh out later in this paper, as we pursue ideas for genetics, there is excellent empirical research that shows that the obligatory nature of finiteness in root sentences develops slowly over time. There is also excellent empirical research that shows that the obligatory production of direct object clitics (in languages that have such) in particular semantic contexts (as opposed to the surface omission of these direct object clitics) also develops slowly over time. Moreover, the time course of development of these two very different appearing surface phenomena appears to be quite similar. There is a unified theory of development (the *Unique Checking Constraint*; UCC) that explains why these two phenomena occur and why their time courses should be similar. That is, the two phenomena are explained by the same constraints on the underlying computation, so that as the computation develops, the phenomena appear to develop in similar ways. Hence, we have a deeper sense of linguistic development than when surface phenomena were studied only in their own right.

Moreover, the unification has helped us to discover more properties of the unified constructions. For example, the UCC predicts that object clitics will be sometimes omitted by a young child, but it does not predict that the clitics will

be used in the wrong semantic context, or that clitics might be placed in the wrong syntactic position, for example, after the verb when they should be before the verb. These predictions turn out to be empirically correct.

The general argument of this paper is that adding the problem of genetics to the problem of explanatory adequacy and the problem of unification to linguistic development has the potential for uncovering further unification, in this case across another level of inquiry, the genetic level, that is the causal level of development. In addition to possibly discovering more about how the genetics of language works, we might find, as we have argued, that we have discovered more about the particular developmental linguistic phenomena that we have identified, and ultimately about the nature of human language itself as understood in linguistic theory. These are possibilities when we study genetics: unification and discovery in the scientific study of language.

The central specific proposal of this paper is that an important avenue for studying the genetics of grammar is to study the genotype corresponding to the phenotype of the UCC. In particular, we can look for the genetic basis for the development of finiteness, clitic omission and related phenomena. Just as for cognitive phenomena in general, we only have extremely tentative understandings of the physiology of the brain that allows us to compute linguistic representations, for example, some locational phenomena, some time course phenomena, etc. (see, e.g., Friederici, this issue). We have no idea how neurons interact to compute the representations. Since science now knows that genetic systems not only play a major role in inheritance but also help to guide the actual workings of cells and their interaction, we might ultimately also understand the physiology of language in a much deeper way if we can make progress in the study of genetics. This is another possibility of unification and discovery. There is no reason to believe that understanding of neuroscience must precede genetics; in any particular case, the exact opposite discovery course might be the more available route to understanding the systems.

The unification of the development of finiteness and object clitics is not the only example of unification that the study of linguistic development has given us. Another prominent example is the development of many kinds of seemingly unrelated "constructions" that have been unified in the study of the *Universal Phase Requirement* (UPR) as discussed in Wexler (2004a, among many later papers). The UPR was created to apply to the development of verbal passives and raising constructions, a unification that had already been carried out in the earlier *A-Chain Delay Hypothesis* (ACDH) by Borer & Wexler (1987). The ACDH had a particular empirical problem: it predicted, contrary to fact, a late development for the movement of subjects from the VP to the Tense Phrase. The UPR solved this problem.

Once the UPR existed, it not only unified existing phenomena, but it predicted entirely new phenomena. For example, the UPR predicts that the development of specificational copula sentences (like *The winner is Mary.*) is a very late development, as late as that of verbal passives and raising constructions (around 8 years of age). This is an extremely surprising prediction, as the surface form of the specificational copula (*DP is DP.*) is very simple. However, unpublished experiments to date confirm the prediction (Hirsch & Wexler 2008). Unification, once again, can play a strong role in discovery.

Similarly, the UPR predicts that the grammar of tough-movement will be considerably delayed (Wexler 2013a), similar to the delay in the grammar of verbal passives until around age 8 (precise up to the limit of available experimental data and current methods). This too is amply confirmed; see Wexler (2013a) for a review of the experimental data.

The predictions are obvious: whatever genetic events underlie the development of verbal passives will be the same as those underlying the development of specificational copulas, or tough-movement, for example.[1] These genetic phenomena are predicted to go together. For example, if there is a genetically caused severe delay in one piece of grammar (e.g., verbal passive), the same piece of genetic machinery should cause the delay in another (e.g. specificational copulas). Of course, such an assumption could be wrong; there might be alternative genetic causes of two pieces of delay that affect two different constructions. But the default working hypothesis, the one that a scientist would always start with is that there is one cause. If it is wrong, the experiments that will show that it is wrong will hopefully add additional insight.

3. Lenneberg's View of Linguistic Development: Biological

Although Lenneberg did not have any of this knowledge of grammatical development to aid his arguments, he made the best use of the empirical material at hand and saw the general structure of how language developed in a biological framework. We can see how the arguments and proposals that we have made so far fit within his general arguments.

First, Lenneberg understood that the development of language in an individual child must be the result of biology, of maturation:[2]

> We must assume that the child's capacity to learn language is a consequence of maturation because [...] the milestones of language acquisition are normally interlocked with other milestones that are clearly attributable to physical maturation [...]. (Lenneberg 1967: 178)

Maturation only became an important researchable topic in generative studies of acquisition with the publication of Borer and Wexler's (1987) independent argument that it best explained some particular linguistic developments (and late developments). Even after that, maturation was looked upon with suspicion in much of the field of language acquisition. Lately it seems to have become more mainstream, among generative acquisitionists at least. Lenneberg saw it in 1967, without the detailed knowledge of grammatical development that went into its later appearance, the reason I called a paper on the maturation of finiteness "Lenneberg's Dream" (Wexler 2003, 2004b). See Wexler (2013b) for further discussion.

[1] There are complications, of course. For example, tough-movement involves not only the need for a weak phase, ruled out by UPR, but also other kinds of mechanisms (see Wexler 2013a). Some of these may have time courses of their own, further delaying tough-movement. More research is needed.

[2] I thank an anonymous reviewer for pointers to the quotations from Lenneberg in this section and for impressing on me the importance of reviewing Lenneberg's contributions to the discussion. I was taking them for granted, but it is better to lay some of them out here.

Lenneberg also saw that linguistic theory plays a central role in understanding language acquisition, and that furthermore, acquisition studies could play an important role in the development of theory:

> The problems involved in language development cannot be understood in the absence of an analysis of the structure of language; and it is quite possible that the proper understanding of language structure is dependent upon empirical investigations into the acquisition process.
>
> (Lenneberg 1967: 275)

Once again, there were very few detailed acquisition results at the time that would have confirmed this view. Nevertheless, the view has been amply confirmed, as witnessed by the actual development of detailed results in developmental linguistics, some of which we discuss in this paper. The field of generative linguistic acquisition may in fact be defined by these views, although it took years to establish them in any kind of convincing detail.

Lenneberg also had a sophisticated understanding of the importance of the connection between genes and language. He wrote:

> DNA molecules [...] probably do no more than control the protein synthesis within a cell. [...] The puzzle now is: [...] how could something like the capacity for language have a genetic foundation? [...] The puzzle is, of course, not peculiar to the problems of the genetic basis of language, but also to the relationship between genic action and the inheritance of traits in general. Although we can only speculate on this point, our speculations with regard to language are no more daring than with regard to most other structural or functional features.
>
> (Lenneberg 1967: 239–240)

On the next page, he continued by saying:

> But, as is well known, genes do not merely control the size and shape of structure but skills and capacities as well. [...] Genes can only affect ontogenesis through varying the cell's repertoire for differentiation, but this, in turn, may have secondary effects upon structure, function and capacities. (Lenneberg 1967: 241)

Against this background, the interface of genetics and linguistics is what we will discuss in the next section.

4. Genetics and Linguistics

In short, we don't know the details of how genes work to influence the computational structure of language within the human, but they must. The logic of the situation is clear. We are in the typical position of studying the indirect relation between genes and function. It is a puzzle, not a mystery. The facts tell us that genetic networks are central to linguistic development. The facts also tell us that linguistic representations are what develop at the functional level. But genetic networks and

linguistic representations are on entirely different levels of analysis. How do we proceed to connect them?

Among relations between biology and language, the relation between genetics and language is not unique in this regard. The situation is quite similar to the arguments of Poeppel & Embick (2005) concerning the relation between neuroscience and language. As they point out, neuroscienctific theory and linguistic theory posit totally different entities (e.g., *neuron* for the former, *sentence* for the latter).[3] No relation has been established between these different levels. That favors neither the neural theory nor the linguistic theory; they both might be accurately describing particular levels. The problem is, can we find any relation between these levels?

Poeppel and Embick argue that in order to make progress on the issue, a theory of the brain should employ linguistic categories, an enterprise not carried out in standard cognitive neuroscience. The argument here is analogous; in order to make progress in genetics, we should attempt to study the relation between genetic networks and linguistic representations. We might start simply, by finding genes that are part of the systems responsible for particular linguistic representations, through the lens of development. That is, what genetic networks are responsible for the development of linguistic representations? This paper makes particular proposals about how we might begin to answer those questions, by including linguistic representations and computations in the vocabulary of what we have to study.

The proposal of this paper is that the detailed and explanatory understanding of grammatical development that we have achieved in the last quarter century can play an important role (obviously not the only role) in creating a wedge into the problem. The argument is that this is a much more promising approach than the traditional consideration of "language" as a general entity, without detail, measured perhaps by a general test of linguistic abilities. Can the latter be the accurate description of language for genetic purposes? No. The facts say that the specific linguistic details matter. I have heard neuroscientists (and perhaps geneticists) describe language as an "emergent" ability. I have no idea what that means. Possibly "emergent" means "mysterious," or "beyond the scope of science." But one can only hope that we can do better than this and create serious science. Indeed, there are distinguished geneticists who have agreed. See Wexler (2013b) for a discussion of the views of Salvatore Luria, a Nobel Prize winner in genetics. There is every reason to believe that Lenneberg would have agreed. As mentioned previously, we will now work out an example, as a proposal.

5. Empirical and Theoretical Tools from Language Acquisition in the Aid of Genetics

What can we use from developmental linguistics to aid us in the study of the genetics of the computational system of grammar? Broadly speaking, anything that will work. In general, given work so far, this obviously includes:

1. The timing of linguistic development of particular pieces of the computational system of grammar. Regularity in timing and particular types of delays

[3] Perhaps Merge would be a better example in discussing syntactic computation. Indeed, some cognitive neuroscientists have sought to operationalise concepts from theoretical linguistics in their work and at least identify their neural correlates (e.g., Friederici, this issue).

help to lump different phenomena into a particular category, which helps in creating predictions concerning which constructions are controlled by similar genetic networks. Of course, this must be done in a theoretical context. We cannot simply study any 20 pieces of development and figure out the appropriately lumped pieces, without a theory connecting them.

2. The variation in time of development of particular pieces of grammar among typically developing children. Rate of development can be used in genetics to attempt to identify responsible genes. One might ultimately find certain genes being activated at particular times, triggering the development of particular pieces of linguistic competence.

3. Developmental linguistic impairments under genetic control. These include (listing only the syndromes whose role in linguistic development has been studied with some clear results): Specific Language Impairment (SLI), Williams syndrome, autism and Down syndrome. We do not have space to consider the extensive literature on particular pieces of linguistic development in these syndromes. However, the genetic logic is clear; if a syndrome shows a delay or breakdown of a particular piece of grammar, we expect that the genes controlling that piece of grammar are implicated in the syndrome. Trying to find these genes (or networks) cross-syndrome could be a very valuable additional attempt.

None of these sources of data and theory are radically different from how genetics generally proceeds when it has been successful. The proposal of this paper is that the same methods that have worked in some other cases can work here, when the phenotypes are linguistic computations, specifically defined from the results of linguistic theory.

The particular case of finiteness and clitic omission that we will detail later in this paper (the UCC, as the affected piece of computation) has been studied in both, (1) its typical development aspect, including delay until a certain age and (3) in its genetically determined developmental impairment aspect. While the focus has been on (1) and (3), even (2) has been studied to some extent; for example, we know that IQ (measuring another piece of cognition) and particular environmental causes do not differentially affect how individual children develop the piece of cognition (Rice, Wexler & Hershberger 1998).

Another desideratum for the study of genetics is that we have a quantitative measure in the behavioral results that can be used as a phenotypical measure to correlate with genetic activity. The finiteness and clitic omission case that we have studied and will explore in more detail below has this quantitative feature. Interestingly, it is only with the development of generative approaches to language acquisition, with their attention to linguistic detail, that these measures have been intensively developed.

6. Toward a Genetics of Grammar

How should we proceed with the study of the genetics and developmental biology of language? We have several relevant sciences at our disposal, sciences that have

substantial achievements. The suggestion of this paper is that these sciences can only make progress in creating a serious genetics of language if they take actual, detailed account of each other. The sciences include:

a. Linguistic theory, which is the description of human linguistic knowledge. It asks: What is the phenotype of language, Universal Grammar (UG) in Chomsky's terms?

b. Developmental linguistics (language acquisition as it is often called), which has sought to describe the changing, developing phenotype and the underlying principles of development.

c. Genetics, with all its methods for determining the physical mechanism of inheritance (and, as we now know, how this mechanism is intricately related to the control of biological systems).

d. Developmental biology of the brain (which, of course, is related to genetics).

Of course, there are other sciences, and these might have a useful role to play and should not be excluded prematurely. It is worth noting, however, that a standard suggestion that we root the study of linguistic development (and thus of a related genetics, presumably) in results from cognitive psychology cannot be right, if for no other reason than that there are very few results from cognitive psychology that seem directly relevant to what we know of language and its development, at least if we are talking about the central computational system of language.[4] There is no general model or theory of cognition that we can use that will help us, none that has any of the appropriate detail.[5]

[4] There are a few intriguing experimental results that might play a role. For example, the (now controversial) observation that certain Theory of Mind (TOM) abilities develop rather late in the child's development (Wimmer & Perner 1983, and a large later literature) might potentially be of some use in the study of a developmental biology/genetics of language. However, most of the development of the computational system of language does not seem to have anything to do with TOM (particular kinds of pragmatic abilities might be related). It is not clear that TOM has much more relation to the development of grammar than it does to the bat's use of sonar. Nor is there a serious understanding of why TOM develops late, if it does (see the work of de Villiers 2007 who argues that in fact TOM develops based on the development of certain linguistic categories, in particular the propositional attitude verbs). One positive argument for using TOM is that it seems to have a particular physical location in the brain (Saxe & Kanwisher 2003), so that an attempt to relate the development of TOM to the development of these particular brain areas might be a help with genetic studies. Nevertheless, we have no reason to believe that the development of TOM has anything to do with the development of grammar.

[5] Another intriguing area of psychological research (Carey 2010, and a very large literature) involves the result that the development of the natural numbers (that is, the crucial recursive step that is at the basis of the concept of natural numbers) is a surprisingly late development. It seems that the natural numbers develop in the brain at a later age than much of the computational syntax and semantics of language, a system that seems much more complicated. This comparison of the rapid development of grammar with the very slow developmental of numbers shows us something about the developmental biology underlying the two systems. But it is not clear that it can tell us something useful for the detailed development of the genetics and developmental biology of language. So far as I can tell, none of the ideas based on learning models that have been proposed explain the late development; rather they stipulate that the recursive step is greatly dispreferred, which is supposed to explain why the basic property of

In the next section, we will present results from studies of the developmental phenotype of grammar that might be central in the development of a potential genetics and developmental biology of grammar. We will point out predictions that would follow from what is known about the different types of constructions that should (and should not) share the same developmental basis. The goal is to attempt to add some small thoughts to what might actually work in the development of a new science. Unsurprisingly, this new science is best aided by starting from what is actually known in existing, related sciences.

7. Unique Checking as a Phenotype for Early Grammar

The first phenotype applies to quite early grammar, to about the age of 3 (depending on language and child). In general, a fundamental property of computational syntax is the necessity for features to check (or match in certain ways) other features. This checking process is necessary in order to carry out *Merge*, the fundamental operation of the computational system of language, called syntax. The operation puts two phrases (in the broad sense) together, forming a larger phrase, allowing not only what we think of as phrase-structure, but also merge operations that connect non-local phrases (including but not limited to movement operations). Such a checking process is a necessary part of the derivation of a sentence, allowing formal (uninterpretable) features to be eliminated so that a structure is completely interpretable. Although interpretable features might be thought of as coming from the

the natural number system is late. Not only is this a stipulation, but it does not account for the fact that recursion in the grammatical system is much earlier. There is no obvious reason as to why, for example, the basic property *Merge* could not recur in young children. Why should grammar be so far ahead of the natural numbers? Furthermore, accounts of the development of the natural numbers show that they need to be taught with a series of rather specific steps. The children are taught to count pointing at objects, and it is a matter of years before they realize that the number of the last counted object represents the cardinality of what is counted. Recursion in grammar, on the other hand, simply emerges, it is what humans do, including young human children.

Here is a tentative suggestion about what might underly the slow development of the natural numbers, based on another suggestion that I think throws light on the relation of integers and grammar. In an important and original paper, Fox & Hackl (2006) argue that all scales that the linguistic system uses are dense. (A scale is dense if for any two members of the scale, there is another member of the scale in between them.) Our physical world, as understood by classical physics, is dense. The system of integers, of course, is not dense (there is no integer between 6 and 7, for example). The argumentation of the paper is subtle, and we cannot go through it here. But, accepting the conclusion, we might speculate that, while grammar, including its semantic component that includes the notion of scale, easily allows the development of dense scales in children, non-dense scales like the integers are not natural—they are developed with much cultural work. This is non-intuitive, I agree; we think of integers as simple. But the developmental results say they are not human-simple, in the sense of easily developing, without instruction. We might speculate that it was natural for language to evolve using dense scales in the semantic component; after all, our cognitive systems were used to dealing with the physical world in, for example, vision, where scales are non-dense. These speculations of course remain to be tested. For our purposes, they might suggest that the development of the integers relies on a learned, in fact, *taught* process, using general purpose abilities. It might turn out that language is necessary for learning integers only because we need to use language to teach the integer system. If these speculations are correct, we may not find a component of the human genome that is distinctly related to integers, as opposed to whatever our general learning capacities are.

interface semantic component, the uninterpretable features are necessary so that merge can operate correctly.

This first phenotype in child grammar restricts the ability of a phrase to check uninterpretable features against other features (usually interpretable). In general an interpretable feature on a phrase (typically a noun phrase, a DP in current terms) can check an unlimited number of features, so long as the right configurations hold. There is no bound or limit on how often the feature can check, thereby eliminating uninterpretable features. This is the way the computational system of language works in adults. In very young children, however, this unlimited checking capacity is instead limited, to one checking relationship. Once the interpretable feature has checked one uninterpretable feature, it is frozen, in a certain sense, not allowing it to check any further features. This is what Wexler (1998a) proposed as the above-mentioned UCC, defined in (1).

(1) *Unique Checking Constraint*: An uninterpretable feature u may only check one feature. Once u has checked a feature it may not check any further features.

An important example involves finiteness, the necessity for a root sentence (with rare, quite particular exceptions) to be tensed. In English and almost all European languages, for example, finite tense must show up on the verb.[6] In English or Dutch, this finite tense is *past* or *non-past*. Taking English as an example, the morpheme *-s* indicates 3rd person present tense, as in the verb *goes*:[7]

(2) a. She goes to the store every Friday.

b. * She go to the store every Friday.

(3rd person singular but does not have the *-s* morpheme)

c. * I goes to the store every Friday. (present tense but 1st not 3rd person)

Children developing English until about age 3 often say (3b) instead of (3a).

(3) a. John like Mary.

b. John likes Mary.

They omit the necessary tense marking *-s*. This phenomenon of young children using the "infinitive" instead of the tensed form is widespread in the world's languages, widespread enough that it has a name: the Optional Infinitive (OI) stage or the Root Infinitive stage, indicating the same phenomenon.[8,9]

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6 In some configurations of tense and agreement, the tense might not actually be audible. This is irrelevant to the point, which involves the central system of syntax, not spell-out (the phonetic realization). As we shall soon illustrate (4), the fact that the errors induced by the UCC can complicate the phonetics helps to prove the point, with acquisition evidence.

7 In all examples that are to follow, an asterisk (*) in front of a sentence indicates that the sentence is not well-formed in the adult language. The computational system marks it as such.

8 While widespread the OIS is not universal. In Section 9 we will discuss the well-known computational reasons (the UCC plus the positive null-subject setting) for the lack of this error in particular kinds of languages.

9 This phenomenon was called the OI stage in Wexler's (1990, 1992, 1993) original formulation to stress the fact that finite sentences in general existed alongside the (non-adult) nonfinite sentences in the child's grammar. Rizzi (1993), accepting the facts in Wexler's paper, called

Lest one thinks that the child error in English simply reflects some kind of surface omission of tense (*go* replaces *goes* because *-s* is omitted in the production of the word), we should look at a Dutch example. In Dutch the first person singular present tense is indicated by the root form of the verb (4a). The infinitive is phonetically more complicated and adds *-(e)n* (4b). In the OI stage, children will incorrectly substitute the infinitive for the finite verb, complicating the phonetics, but showing the preference in many cases for the nonfinite form of the verb. Such a phonetic complication quite often exists in many languages in the OI stage; this error is one in the computational system of language, the syntax, not in the phonetics.

(4) a. werk
b. werken

Schütze & Wexler (1996) investigated a generalization about the form of the subject pronoun in child grammar in English during the OI stage. Children often produce the Accusative (non-NOM) form of the subject pronoun instead of the nominative form, using *him/her* instead of *he/she* as in (5).

(5) her/her go

However, a striking generalization first discovered by Loeb & Leonard (1991) and further confirmed in Schütze and Wexler's data, as well as in Schütze (1997), is that the accusative (non-NOM) form of the subject pronoun is only used when the verb is non-finite:

(6) a. # Her goes. (# means does not occur)
b. Her go.
c. She goes.
d. She go.

At the same time, children will produce the nominative form (*he, she*) with a finite or non-finite form (6c and 6d).

Schütze and Wexler explained these generalizations in the following way: Nominative is standardly assumed to be assigned/checked by agreement (between the subject and the verb, done in terms of features; we will not explain an exact implementation). Verbs have an agreement feature and a tense feature. The agreement feature of a finite verb assigns/checks Nominative case. Children in the OI stage sometimes omit AGReement and sometimes omit Tense. For simplicity we can assume that just one of these is omitted (or neither, which then results in an adult sentence such as 6c). If AGR is omitted, but Tense exists, then tense is spelled out (e.g., *went* in past tense) but the lack of AGR means that NOM is not checked, so

it the Root Infinitive (RI) stage in order to stress the fact that the nonfinite sentences (with infinitival verbs) existed in root sentences (main clauses), whereas they only appear in embedded (subordinate) sentences in adults. As it turns out, the effects of non-finite sentences in the child grammar can be seen also in embedded sentences where nonfinite properties replace finite ones. See Wexler (2011) for detailed evidence, especially concerning OI children's extensive omission of the non-finite Tense marker, *to*, in English. So I would conclude that OI is a less misleading term than RI. Nevertheless, either term will be understood in the field as indicating more or less the same phenomena.

that default case (one not needing checking by one of these features) is invoked. In English it is well understood that accusative (non-nominative) case is the default (it is different from language to language). Children know the default form for English, so they use accusative (non-nominative) case for the subject when AGR is not in the structure. Moreover, the lack of Tense means that the verb does not have the present or past tense feature, resulting in the root form of the verb. This yields (6b). Now, suppose that AGR exists in the child's derivation but Tense does not. NOM is now checked (by AGR) and *he/she* occurs in the subject. However, Tense is omitted, so that again, in 3rd person singular, *-s*, which demands both an agreement and tense feature, cannot appear. The root form of the verb appears with a NOM subject (6d).

Crucially, one form that occurs only very rarely is the combination of accusative (non-nominative) in the subject and *-s* on the verb (that is, a finite verb). This is because the existence of *-s* indicates that AGR exists on the verb; thus the subject must be NOM. (6a) is predicted to not exist in the child's grammar, as indicated by the # mark, which means not part of the child's grammar.[10] Schütze and Wexler argued that the child omitted either AGR or Tense. This was the AGR/Tense Omission Model (ATOM) of the OI stage. Wexler (1998a) proposed that ATOM held because there was a limitation (the UCC) on the child's computational capacity. In particular, to derive a finite English sentence, the grammatical subject has a feature that must check a feature of AGR and a feature of Tense.[11] Since the subject's feature is interpretable (as a referential feature, say, or a determiner feature), it can check AGR, eliminating this uninterpretable feature, and likewise check Tense, eliminating its uninterpretable feature.

Wexler argued that the UCC as defined in (1) prevents the child from checking both the AGR feature and the Tense feature. This would result in an uninterpretable feature remaining in the derivation. This causes a crash of the entire derivation, and the sentence simply cannot be derived by the computational system. The child omits either AGR or Tense so that the derivation does not crash. This results in the set of phenomena described by ATOM. Note that the UCC results in a smaller set of derivations being grammatical for the young child than in the adult language. This is a general property of the phenotypes that we will discuss. As biological developmental processes take place, they expand the set of computations that the computational system computes as well formed.[12]

[10] Pine, Rowland, Lieven & Theakston (2005) argue against the generalizations discussed here, based on data in Manchester (i.e. British) English. I don't have an explanation for this data, which goes against the data on American English that has been reported. Perhaps there is a special property of Manchester English that allows for what appear to be non-NOM pronouns in subject position with a finite verb. Some kind of pragmatic emphasis, for example, as has been suggested exists in Irish English.

[11] The feature can be thought of as a D feature or as an EPP feature, depending on the particular grammatical model.

[12] See Wexler (1998a, 2004b) for an explanation of why the child sometimes violates UCC, allowing a grammatical finite sentence.

8. Genetics of Unique Checking

At this point, we have identified the UCC as a general limitation on linguistic computations. One of the important features of this model is that it makes predictions about which structures will develop at the same time or not. We will suggest that the UCC is genetically determined; it is a piece of biological development. Biology (genetics) determines when the UCC is no longer a limitation on the child's grammar.[13]

Just like any piece of developmental biology, this development takes time to unfold. Accordingly, Table 1 (Dutch data, typically developing children) shows how the nonfiniteness of verbs that are finite in adults is a diminishing fact of child grammar.[14] Although this table shows average data for a large group of children, it is also true that when longitudinal investigations are made, it turns out that the rate of nonfiniteness within an individual child also reduces incrementally with time. This is not a one-step process that takes place in a very short time, as we might expect from a piece of learning or insight. Rather, the child's genetically determined linguistic capacities unfold over time, just as physical growth processes do (e.g., teeth do not emerge full-blown; they grow over time).

age group	% OIs
1;07–2;00	83 % (126/152)
2;01–2;06	64 % (126/198)
2;07–3;00	23 % (57/253)
3;01–3;07	7 % (29/415)

Table 1: Proportions of Dutch root infinitives by age (from Wexler, Schaeffer & Bol 2004).

The obvious claim is that this effect of the UCC—the finiteness development over time—is genetically determined. Is there evidence? Yes.

First, there is a good deal of behavioral linguistic evidence that the slow rate of finiteness development is not caused by learning, that is, by environmental factors. Standard causes of learning that affect other cognitive/linguistic capacities (e.g., the strong effect of parental education and child IQ on vocabulary growth in the young child) do not have an effect on the development of finiteness (Rice, Wexler & Hershberger 1998).

Second, standard behavioral genetic experiments on twins show that the phenotype of the OI stage (development of finiteness) is strongly inherited (Ganger, Wexler & Soderstrom 1997, Ganger 1998) and that its inheritance is independent of memory abilities, in particular of phonological working memory (Bishop, Adams & Norbury 2006). This latter twin study estimates a heritability rate (*h* squared, that is the proportion of variance in performance on finiteness that is due to genes) of about .73 on the finiteness measure.[15] That is, variations in finiteness are mostly at-

[13] Other models of the OI stage, for example Rizzi (1993), will make quite different predictions from the UCC, for genetics as well as for development, even if they assume maturation as the underlying cause of development. That is, most of these models will not predict the developmental or genetic correlation between finiteness and object clitics that we later discuss. It is of course a serious virtue of the generative approach to linguistic development that there are detailed models with divergent predictions. One of the advantages of the UCC is that it makes these developmental correlations explicit, finding the cause of late development to be in a computational syntactic constraint rather than in a special property of subject positions.

[14] Children with SLI also show this slowly diminishing rate of non-finite sentences, although over a much more extended period, as we discuss in Section 9.3.

[15] I have estimated this number from the graph given in Figure 2 of the referenced paper.

tributable to genetic differences. Meanwhile, other measures (e.g., vocabulary size) are *not* attributable to genetic differences.

Third, there is even some evidence concerning the physical location of genes underlying the development of finiteness. Falcaro et al. (2008) studied impaired children on a measure of finiteness in English (% correct use of past tense in obligatory past tense contexts, in an elicitation experiment), also comparing the results to a phonological working memory (non-word repetition, NWR) measure.[16] We know from Schütze & Wexler 2000 that the past tense error in English is essentially never the use of the wrong tense (in this case present tense); rather it is the use of a non-finite OI form. Falcaro et al. also took DNA from the participants, performing a linkage analysis for both measures in candidate regions. Simplifying their results, NWR linked to a region on chromosome 16 and the past tense (finiteness) measure linked to a region on chromosome 19. A major question for research is whether finiteness in general is linked to chromosome 19 and whether other grammatical impairments, developing at a much later age, are also linked to that chromosome (and the same region) or whether they are distinctly represented genetically.

An anonymous reviewer asked about whether there is evidence concerning the development of verbal passives in SLI. If SLI children are delayed on verbal passives, and if the late development of verbal passives is an independent genetic event (as suggested by the very late timing of development compared to finiteness), why should the SLI syndrome show impairment on both these constructions? This is a difficult question in genetics that often goes under the name of co-morbidity. Why are there different pieces of competence impaired if they in fact might be independently determined by different pieces of genetics? One possibility is that they are not independent, that the same genetic event is the cause of both. But then, why is their time course so different (3;6 for finiteness development versus 8 years for passives)? One answer (if the data show co-morbidity in this domain) could be that there is something in the genetic pathways that goes from the genetic basis for finiteness (the UCC) to the genetic basis for the verbal passive (Universal Phase Requirement). There is no simple a priori answer, but it falls within the realm of research.

At any rate, as the reviewer suggests, evidence from linguistic development in the syndromes is very relevant. There have been a few studies on verbal passive in children with SLI, but so far as I know there is no published study that tests psychological (subject experiencer) verbs, which are the crucial determinant of late development of passive.[17] The only data I know are from unpublished work by Perovic & Wexler (2014). They show that children with SLI (mean age 130.5 months) do have a deficit in subject experiencers when compared to a somewhat younger group of typically developing children. So there might very well be a verbal passive deficit in SLI, although we should be careful because the sample included younger children. Children with SLI were able to use an adjectival interpretation to under-

[16] We will discuss later why noise was introduced into their data given both the age of children studied and the particular measure that they used, and will propose a genetic experiment that might produce clearer results.

[17] See Borer & Wexler (1987) and a large subsequent literature that convincingly shows that children's performance on verbal passives of "actional" (e.g. Agent/Instrument subjects) verbs is greatly aided by a strategy that interprets these as adjectival passives.

stand "actional passives," just as typically developing children do but, as the paper shows, children with autism and language disability cannot.

More research is needed, not only genetic but also developmental linguistic in nature, to determine whether a child who inherits genes that determine the late (if ever) growth of finiteness also inherits genes that determine that late (if ever) growth of the verbal passive (i.e. UCC implicates UPR). If so, we need a genetic model that predicts such. Not quite as straightforward as independence, but not impossible.

There is experimental biolinguistic evidence concerning verbal passives and related constructions that lends credence to the idea that this piece of maturation of the computational system is in fact genetic. In behavioral genetic research, Ganger, Dunn & Gordon (2005) showed that identical twins inherit the ability to understand the syntax of verbal passives. In particular, the development of subject experiencer passives is much closer in identical twins that in fraternal twins. The development of verbal passives of "actional" verbs does not show this effect; the adjectival strategy is a piece of learning/strategy in children, not of inheritance.

There is also research on genetically caused impairments that contributes to the biolinguistic argument for the UPR. For example, Perovic & Wexler (2006, 2010) compared the development of "actional" and subject experiencer passives in children with Williams syndrome, and concluded that these children had

> a particular difficulty with the structure of the verbal passive, not directly related to general levels of nonverbal abilities, receptive vocabulary, or general comprehension of grammar.
>
> (Perovic & Wexler 2010: 1294)

They argued that the development was due to a genetically caused delay in the development of argument-chains, now subsumed under the UPR.

9. Proposal for a Study on the Development of Finiteness[18]

Much—if not most—remains to be done in this area. We need studies that investigate in detail how the development of finiteness is genetically determined, in many languages. In this section, I will propose one such study.

English is not the best language in which to pursue the investigation of the genetics of the development of finiteness. The reason is that the "infinitive", that is the nonfinite form, does not have a distinctive marker; rather in 3rd person singular present tense, the finiteness (tense and agreement) marker *-s* is omitted to give the nonfinite form that is the root of the verb. So first, only 3rd person singular contexts in present tense or the omission of the past tense marker *-t* in past contexts can be used as a measure of the OI stage. Moreover, omissions can sometimes occur for other reasons than finiteness. In fact, the history of developmental psycholinguistics is replete with the error of thinking that only omission errors are made, not

[18] In this paper I am discussing almost no genetic detail, particular genetic mechanisms. I am concentrating instead on why I think that particular phenotypes are crucial for obtaining genetic results. For some interesting ideas that attempt to suggest more particular hypotheses about regulation and timing in cells that would relate to the types of phenotypes I am discussing here, see Rice (2012).

errors of substitution of one form for another. This error was due to the unfortunate concentration of so much of the research in early developing grammar being based on English, with its impoverished morphology. We get a much better sense of how the OI stage works in a language in which there is a particular marker for the nonfinite form, like the *-n* in Dutch that we mentioned. So we should look for such a language in which to do a genetic study.

Which language should this be? Familiar genetic considerations suggest that Icelandic would be an ideal language to carry out a study of the genetic basis for the development of finiteness. First, there is a genetically much more homogeneous population in Iceland than in most other countries. Second, there are extensive records in Iceland of family histories. These two factors have combined to make Iceland a place which can offer substantial benefit for the study of human genetics.

First we have to answer a technical linguistic question about Icelandic, the language of Iceland. I mentioned that not all languages have an OI stage. Does or maybe better, *should*, Icelandic have one? The UCC actually makes a prediction about this. Wexler (1998a) argues that in languages that have "null subjects", that is the strong (prevalent) possibility of the non-pronounciation of the subject of a finite verb, there is no AGReement feature to check because the AGReement feature is interpretable, in fact interpretable as the subject. Only noninterpretable features have to be eliminated, so there is no need to eliminate the AGR feature. Therefore, there is no need for the subject to check the AGR feature. This means that the subject has to check only one feature, Tense, and the UCC is not violated, since there is not more than one feature that has to be checked. A finite sentence in a null-subject language is therefore grammatical for the child's grammar, even when the UCC holds. Thus there is no reason to omit the Tense or AGR feature and the child's grammar of a null-subject language derives finite sentences in a totally adult way. The prediction is that the phenomenological OI state (the use of nonfinite sentences when a finite sentence is derived in the adult grammar) does not exist in the development of a null-subject language. This prediction is true (see Wexler 1998a and many other references). Now, Icelandic is not a null-subject language. We therefore predict that Icelandic should have an OI stage. A study was done in Sigurjonsottir (1999) and indeed it turns out that Icelandic has a quite strong OI stage.[19]

What kind of studies would be most likely to attain results? There are several possibilities that we should explore, where Icelandic experiments would be ideal, for the reasons given, but many other languages qualify.

[19] This study on Icelandic actually provided a particularly important result in distinguishing between two potential generalizations concerning which languages underwent the OI stage. The null-subject property was one idea. Another idea was that the languages which contain rich agreement were the ones that did not undergo the OI stage. Mostly, the two predictions overlap; most typically, rich agreement and the possibility of null-subjects correlate. Icelandic, however, has rich agreement but is not null-subject, thereby providing a testing ground for the correct generalization. It turns out that the null-subject idea was right, thereby providing evidence for the UCC model that derives NS/OI.

9.1. Typical Children

One can study a population of typically developing children, who will progress out of the OI stage at different rates. Various measures of development can be used: Relative amount of finite verbs in obligatory contexts at a given age (Wexler 1990, 1992, 1993), age at which a developmental criterion of percentage production of finite verbs in obligatory contexts is reached (Ganger, Wexler & Soderstrom 1997), number of correct judgment of the non-grammaticality of non-finite sentences or a measure from signal detection theory (Rice, Wexler & Redmond 1999) among several others. These same measures can be used in the methods discussed in the next sections. One can attempt to link time of development to time of activation of particular genes. The general idea is that variation in timing of the phenotype will lead to knowledge about the genetic structures involved.

9.2. Twins

One can study Icelandic or other languages identical and fraternal twins against some measure of the OI stage, for example, the % of finiteness in obligatory contexts at a certain age, or a measure of when a particular criterion is reached, etc., and try to establish that identical twins are more closely related on this measure than are fraternal twins, thereby confirming the hypothesis of genetic determination for exit from the OI stage, as the studies mentioned above did in English. In linkage and other genetic studies, it might also be possible to determine actual genetic differences in fraternal twins (or siblings) that lead to differences in the OI stage.

9.3. Specific Language Impairment

In OI (i.e. non-null-subject) languages, SLI has a very delayed OI stage called the Extended OI Stage (EOI; Rice Wexler and Cleave 1995, Wexler 1996, and many other references). The prediction is that the Icelandic populations will include children with SLI, characterized by a very late development of finiteness (EOI). So far as I know, Icelandic has not yet been studied from this point of view.[20] It is straightforward how to accomplish such a study of SLI: One standard way is to identify (in clinical settings, or in schools) children with a language problem but no obvious sign of any of the standard physical developmental delays (Down syndrome, Williams syndrome, autism, etc. and no mental disabilities (low IQ, etc.). Experimental linguistic tests are then given to determine facts about finiteness. We expect an EOI stage, a lack of finiteness, to show up among children older than the typical age for exit from the OI stage. Since we now have a non-typical population, one might look for genetic differences between the typical and SLI populations, linkage and other studies. There might actually be such differences responsible for SLI. If we find a genetic cause of this difference in finiteness between groups of SLI and typically developing children, we can hypothesize that it is the cause of the UCC. The simplest hypothesis is that the genes responsible for causing SLI

[20] A reviewer points out Thordardottir (2008). So far as I can see, the relevant data are not in that paper, but one might look further into it.

are the same genes whose varying time of activation across typically developing individuals cause different development patterns of finiteness in these individuals.

The best evidence we have supports the hypothesis that children with SLI never completely develop the grammatical underpinnings of finiteness: teenagers with SLI who start to perform well on simple tests of finiteness in declarative contexts do not judge finiteness correctly in other contexts (Rice, Hoffman & Wexler 2009). The hypothesis is that they have learned or been taught in many cases to use finiteness in simple declarative contexts. The children in our studies are either in special classes or have speech and language therapy. Getting the form of the verb correctly in simple sentences is worked on in language instruction, even drilled. There is no reason for children with SLI to not be able to learn in this way, given enough time—they are intelligent. They learn to produce a form in certain contexts. But they do not actually develop the grammar, as determined by other constructions, on which they are not instructed.

In particular, Rice, Hoffman & Wexler (2009) have shown that even teenagers with SLI do not have the finiteness requirement. They asked participants to judge the grammaticality of finite and non-finite questions (e.g., *What he drinking?*), all of which omitted either a form of *be* or a form of *do*. There is no reason to think that these simple questions are used for systematic teaching of the requirement for finiteness in children with SLI. The participants with SLI very often judged the non-finite sentence as grammatical, whereas the typically developing control participants did not. There was very little advancement with age. Even at age 15, the group with SLI only judged the sentences correctly about 76 % of the time, compared to their (younger, since "language-matched") typical controls, who judged the sentences correctly about 95 % of the time. Differences between groups were even larger than this numerical mean score indicates. The best way to analyze grammaticality judgment data is, as in signal detection theory, to take account of hits and false alarms, with biases, to detect whether participants appropriately distinguish grammatical and non-grammatical sentences. Detailed analyses showed very large differences between the participants with SLI and their controls, on the level of a standard deviation or more at all age groups. Furthermore, there was another control group, participants matched by age to the group with SLI. Differences here were even larger. Finiteness in these question constructions is simply not known at age 15 (possibly longer; those were the oldest children in the study) to participants with SLI.

In summary, the UCC seems to last beyond childhood in children with SLI, perhaps indefinitely, although children at younger ages can be taught to use their general intelligence to learn to produce (and judge) simple sentences correctly. This result further suggests that one can find genetic differences between the typical and SLI populations. Since Icelandic has a clear infinitival marker and is not a null-subject language, as we have pointed out, we expect to find an OI stage in the language, and this expectation is confirmed. Likewise, we expect to find an EOI stage in Icelandic children with SLI. I propose studying such children genetically, with linkage and other studies, to attempt to find the genetic underpinnings for the slow development of finiteness and more generally for the UCC.

As I pointed out, to the best of my knowledge, there is no study of SLI in Icelandic that has asked the question of whether there is an extended finiteness de-

lay. So pursuing such a study in young children would be an excellent idea and, assuming confirmation, doing the genetic studies on the SLI versus typically developing group comparison, using a measure of finiteness (% use of a finite form in obligatory contexts, age at which a particular % criterion is met, or similar) as the phenotype. Given the clear Icelandic pattern expected and the relative genetic homogeneity of the population, we might hope to find a clear genetic marker in this Icelandic population of the UCC. Large families with family history recorded might also be a good source for the study of the inheritance of SLI, although there will in all likelihood not be any record of measures of finiteness in childhood records of older populations. One possibility of overcoming this latter problem would be to take advantage of the finding in English that competence in finiteness is delayed for an older population of children with SLI if ones uses the proper experimental methods, namely constructions in which a child might not have been instructed during language therapy (Rice, Hoffman & Wexler 2009). In particular, we can use such methods on older children, parents and grandparents, while still using production measures on very young children, all of these methods resulting in a measure of use of finiteness in obligatory contexts. It might even be possible to establish these non-production methods on an impaired older population that might reflect SLI.

The goal would be to see if we can establish SLI or not on several generations in a family, and collect DNA to do linkage and other genetic analyses on the extended family, using the determination of SLI or typical, and/or the continuous finiteness measure as the phenotype measure. Of course, once we use alternative measures (ones that the individuals haven't been instructed on), we can study even adult twins (identical versus fraternal) in a similar manner, including genetic studies.

10. English Again

The one study that attempted to link a measure of finiteness (in this case the production of past tense in obligatory contexts) in English to a genetic basis is Falcaro et al. (2008). As hinted at above, their study had two features that provided less that optimal results: First, the measure of use of past tense included overregularizations as an error. For example, suppose the correct form to use in an elicitation of past tense for the verb *go* is (7a). There are two ways that children can be wrong; they can either use an incorrectly regularized form (7b) or use a non-finite, OI form (7c).[21]

(7) a. Mary went to the store.
b. * Mary goed to the store.
c. * Mary go to the store.

The finiteness (OI) error, caused by the UCC, is to use (7c), not (7b) which, in fact represents a (past) tensed form, though with incorrect morphology. Falcaro et al. included overregularization forms like (7b) as errors, counting as correct uses only forms like (7a). Therefore, their measure of correct use is only an approximation

[21] As we have already pointed out above, the wrong tense error *Mary goes to the store.* is almost non-existent.

of the rate of finiteness, and therefore, only an approximation of the phenotype measure of use of finiteness in obligatory contexts, the degree to which UCC is active in a child.[22]

Falcaro et al. do not give tables of each type of response (7a–c) so that we cannot say how much the relevant measures differ in their data. Therefore, we need a genetic study based on the English finiteness phenotype in which the use of a *finite* response in obligatory contexts is given. If there are regular verbs elicited, there is no issue. But if irregular verbs are included, we have to count the overregularized forms as finite. This produces a more accurate measure of the finiteness phenotype.

The second feature of Falcaro et al.'s study that we would like to improve is the age of participants. In general, the OI stage in typically developing English is mostly over at about age 4;0 or 4;5, with only a small number of OI errors after that.[23] The mean age for participants (selected as language-impaired in Falcaro et al.) was 14;5, range 13;1–16;2). The mean age was 44;1 for parents, 18;8 for older siblings and 12;4 for younger siblings. We know from Rice, Wexler & Hershberger (1998) that children with SLI perform near ceiling (over 90 % as a group) at age 8 on finiteness when tested on simple present and past tense elicitations. At this and later ages, they have to be tested on constructions that they are not coached on in therapy in order to once again find large differences between typically developing and SLI children. And in fact in Falcaro et al.'s data even the language-impaired group performed reasonably well on the past tense elicitation. They scored 43.09 out of 52 maximum, for an .83 score of correctness.[24] However, as we discussed

[22] See Rice, Wexler, Marquis & Hershberger (2000) for detailed study of overregularizations versus OI forms in the English of children with SLI. When the overregularized form (*goed*) is taken as a finite form (though with incorrect spellout), the results establish that children with SLI are significantly worse (as always) from younger language-matched typically developing children. On the other hand, when analyzed according to whether the past tense forms that were produced were produced correctly (that is, overregularized or not), children with SLI performed quite similarly to typically developing control groups. SLI shows a problem in the development of finiteness, not in problems with regularization. Redmond & Rice (2001) studied the same question by using grammaticality judgments as well as production data. They concluded that,

> the production and acceptance rates of past tense overregularizations (e.g., *he falled*) by the SLI and language-match groups were similar, and both were higher than the age-match group. (Redmond & Rice 2001: 655)

In other words, on the crucial test of comparison of the SLI and language-matched groups for overregularization, children with SLI perform at the same level as the typically developing children. Only finiteness shows the worse performance of the SLI group and the language-matched group. Overregularization reflects other skills, not the genetically determined slow growth of finiteness. An anonymous reviewer also points out that overregularizations in typically developing children do not disappear when non-finite forms disappear, around 3;6. Overregularizations also significantly occur in null-subject languages, although non-finite forms do not, for reasons we understand. Overregularization and lack of finiteness are two completely different processes. We have no particular reason to think that overregularization variations across children and types of group are genetically determined, unless it's simply genetic determination of a simple learning process.

[23] See Rice, Wexler & Hershberger (1998) and Rice & Wexler (2001) for detailed estimates of the finiteness measure by age based on large populations of typically developing children and children with SLI.

[24] The relatives scored much better, of course, but we must remember that the large majority of participants were parents, mean age over 44.

above, overregularizations were scored as incorrect, even though they had finite morphology. So we would expect the finiteness rate would be considerably larger than .83, although we cannot determine it from the paper, which does not separate out finiteness from overregularization errors.

The suggestion for a proposed genetic linkage study of finiteness in English is thus clear: First, on an elicitation task it would be good to have young children as participants (younger than 4 if typically developing, younger than 7 if SLI). Second, one might study adolescent children (and perhaps adults) using a finiteness task that adolescent children with SLI have been shown to perform poorly on, for example, the task in Rice, Hoffman & Wexler (2009) or other tasks that are first confirmed to show difficulty in an impaired population. Third, if past tense is used, the finiteness rate should be proportion finite in obligatory contexts; if irregular verbs are part of the stimuli, they should count as "wrong" for this measure only if they are OIs, the root verb, and not an overregularization. Fourth, it would be worth expanding the elicited forms to include at least 3rd person singular present tense, as in many other SLI studies, so as to obtain a wider variety of examples of finiteness. One might even include examples with auxiliaries and copulas, which are understood to be omitted as part of the OI stage. The hope is that this more precise phenotypical measure will produce a stronger and clearer genetic result, when linkage studies are attempted.

11. Object Clitics

Lastly, we now want to consider a potential genetic study that would speak to a deep and fairly often misunderstood aspect of the biological theory of the UCC (and which applies more generally as well). The UCC is a hypothesized phenotype that is more general than a particular linguistic construction or small piece of competence. Rather it is a limitation on mechanism, in particular on the computational theory of language, that applies to a variety of constructions and what look like pieces of language competence. One of the (many) arguments for this limitation on mechanism in fact is this ability to predict developmental patterns in such strikingly different pieces of phenomenology.

We may think of the UCC, then, not as the description of a low level phenomenon, a particular piece of phenomenology, but rather more like an *endophenotype*, a term coined by John & Lewis (1966) and since then widely adopted. The idea is that the proper description that relates to genetic causes is not a particular behavioral phenomenon, but something more internal and general. In the case of the UCC, it is not use of "finiteness" that should be related to a genetic cause, but rather the UCC, a limitation of a particular kind on an internal piece of the computational mechanism of language. We should expect that this piece of the computation should affect several kinds of "behaviors," in our case several kinds of linguistic constructions.

One of the more developed and striking uses of the UCC is to a construction that appears to have nothing to do with finiteness, namely to the domain of object clitics. Since direct objects do not have any particular relation to finiteness (in contrast to subjects), a more low level description of the phenomenon of the development of finiteness would not think to put it together with the development

of object clitics. However, it turns out that the UCC applies to both finiteness and object clitics, with particular and different effects on each development. An object clitic is a reduced pronoun that, in many languages, appears before the verb instead of the usual position of an object (in those languages) after the verb. An example is given in (8) below.

(8) *French*

Jean la voit.
Jean CL-her sees

'Jean sees her.'

Here, the object is the clitic pronoun *la*, that appears before the verb; if instead of this clitic a proper noun (*Mary*) or definite description (*the woman*) was the object, it would appear *after* the verb. In general, pronominal clitic objects like *la* are referentially dependent; they refer to an established entity in the discourse.

The most obvious phenomenon in the development of object clitics is that children before about age 3 very often omit them, in French or Italian and other languages. One might think that this was a case of omission of a phonetically light element (for whatever reason). However, one strong argument (among several) that the explanation is more syntactic is that in many languages (e.g., Greek, Spanish, Bulgarian, and Albanian), children omit very few direct object clitics, although they are phonetically reduced just as in French or Italian. Wexler (1998b, 2014) showed that the UCC predicted clitic omission in languages like French and Italian in which children indeed omit large numbers of clitics. As predicted, the age of clitic omission corresponds to ages of the OI stage (lack of finiteness) in those languages in which children often omit finiteness. Wexler (2002), Wexler, Gavarró & Torrens (2004), Tsakali and Wexler (2004), as well as Gavarró, Torrens & Wexler (2010) showed that the UCC predicted no omission for particular kinds of languages (those in which the participle did not agree with the object clitic. Some of these papers showed that the prediction was correct for Spanish and Greek. Kapia (2011) showed that the UCC predicts no omission for Albanian, and that the prediction is correct. Radeva-Bork (2012) showed that the UCC predicts no child clitic omission in Bulgarian and that the prediction was empirically correct. The essential idea is that in languages like French and Italian, which show participle agreement with the clitic, there is a double checking (of the clitic or of an empty object) whereas in languages without this agreement, there is only one checking. Thus the UCC predicts the necessity for omitting a clitic in the former but not in the latter.

The enophenotype, that is the UCC, applies to a wide variety of constructions, predicting particular development behaviors. Often these constructions—pieces of phenomenology—appear to be extremely different from each other. Yet, the UCC is a phenotype on the computational system of language, not a piece of behavior.[25]

[25] Another example of a very different type of construction constrained in children by the UCC is short-form negation in Korean (Baek & Wexler 2009).

12. Proposed Genetic Study of Object Clitics

The findings discussed in the previous section immediately suggest further genetic studies related to the UCC. The obvious prediction is that the genetic substrate of finiteness is also the genetic substrate of clitic omission. So, if it turned out, for example, that Falcaro et al.'s results linking the development of obligatory use of finiteness to chromosome 19 were correct, the same region of chromosome 19 should be linked to non-omission of object clitics. This is a striking prediction; without a particular endophenotypical model, we would be in no position to make such a prediction.

Importantly, the prediction is *not* that all pieces of grammatical development should be linked to the same genetic cause. Only the pieces caused by the computational limitations of the UCC should be so linked. Thus, late development of verbal passives and all the attendant constructions are not caused by the UCC, but by other computational limitations. We do not have time or space to consider these here in any detail, but they have the same general type of theoretical and empirical base as the case that we have discussed, the UCC. That is, the predictions are particular.

What kind of studies should be done? In languages like French, Italian, and Catalan, in which object clitics are omitted (and in which we expect them to be omitted even more often and later in SLI), one can use the clitic omission phenotype (proportion of appearance rather than omission of the clitic in obligatory contexts) and link this clitic measure to genes. In the same language, say, assuming it is also an OI language, one can do the same for finiteness. The genetic substrate (genes, expression patterns, etc.) should be the same for the two measures. One could then add a measure whose development is predicted to be not related to these, that is, not caused by the UCC, and one should not expect the same genetic cause to show up. An example of a language that is both an OI language and a clitic omission language is French, so one might consider such a study in that language. It might not be ideal to use French because, for various reasons, the OI rates are somewhat smaller than in many other languages, probably because of the particular morphological patterns of the language. Some of the Germanic and Slavic languages have a kind of object clitic, not nearly so common as the Romance clitics, that might lend itself to a study of omission. Much more needs to be discovered about particular languages and clitics; it would be ideal for experimental genetic methodology to have a language in which both the OI and clitic omission rates were robust so that genetic determinations on each particular participant could be compared for the two phenotypes.

Studies could also relate a finiteness measure in one language to a clitic omission measure in another language. For example, Italian does not show an OI stage (it is null-subject). But it has a robust clitic omission pattern. (We are always speaking of children or impaired populations, e.g., SLI).[26] If we could find a language L in which the opposite is true: there is a robust OI stage but no clitic omission stage,

[26] For a review of data showing that clitic omission to an even greater age is a pervasive feature of SLI (for the languages that have participial agreement), see Wexler (2004b, 2014) and for very clear evidence (in Greek) that children with SLI in a language that does not show participial agreement do not omit clitics, see Manika, Varlokosta & Wexler (2011).

then we would predict that the genetic basis underlying clitic omission in Italian is the same as the genetic basis underlying the use of OIs in language L.

13. Conclusion

The clitic omission phenotype is very clear. In particular, the experimental methodology that establishes it is quite precise; the best method so far is to elicit clitics in semantic contexts that require them, that is in which there is a clear referential antecedent for the clitic. Even young children seem to know that object clitics are only possible in such contexts. Both finiteness and object clitics have a clear experimental paradigm that establishes their rates in obligatory contexts. Methodologically as well as theoretically, they make a good behavioral comparison for purposes of testing whether they are determined via the same genetic substrate.

One could think of many variations on the kinds of studies that I have suggested in this paper. The essential message is that once we have a computational endophenotype we can investigate the genetic basis for this endophenotype and make striking predictions. My own hunch—against the general direction of the field, which is to ignore the empirically and theoretically determined limitations on computational mechanisms during development, with enhanced limitations in certain impairments—is that paying serious experimental genetic attention to such phenotypes would be a major advantage in beginning the extremely important and intriguing study of the genetics of language, very much in Lenneberg's spirit.

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