PART 4

Grammar and evolution

CHAPTER 11

The role of adaptation in understanding linguistic diversity

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The 6,000–7,000 languages spoken by people display a dazzling variety of sounds, word patterns, and grammatical forms. The dominant explanation for this diversity is that languages drift apart as communities separate. The accumulation of random changes eventually produces languages that are mutually unintelligible. We argue that in addition to this non-functional process of drift, language change and diversification can be explained in functional terms as adaptations to social, demographic, and ecological environments in which the languages are learned and used, a proposal we call the *linguistic niche hypothesis*. We support our position with a series of agent-based models that serve as an existence proof for why language diversity requires adaptation. We next discuss empirical evidence for a link between aspects of socio-demographic factors, ecological factors, and grammatical structure which strongly suggest adaptation to be at work. One mechanism we focus on is language learnability: while all languages need to be learnable by infants, only some languages are further constrained by adult learning biases. Thus, languages which for historical reasons have adult learners adapt to be more learnable by adults. As a result, languages spoken in larger and more heterogeneous environments in which adult language learning is more likely to take place tend to be grammatically simpler than languages spoken in small homogeneous environments. The linguistic niche hypothesis outlined in this chapter, while still in early stages, promises to shed light on longstanding questions such as why there are so many languages, and why they differ so substantially from one another.

1. Introduction[1]

Human groups display a dazzling diversity of cultural practices. Clothing styles, building techniques, cooking practices, art, and legal systems all show enormous

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variability. Attempts to understand why people in equatorial Africa wear different clothes from people in the Arctic would not get far without considering differences in climate. It is rather obvious that traditional cooking techniques are strongly constrained by availability of certain foods and the preparation those foods require. Yet, when it comes to language – another culturally transmitted system showing enormous cross-cultural diversity – the assumption most linguists and psychologists have made is that linguistic variability is not meaningfully related to factors that strongly constrain, or even determine, other aspects of human culture.[2] We argue that – just as looking to the physical environment is necessary to explain differences in cultural practices such as clothing styles and building techniques – looking to the social and physical environment is necessary for understanding at least some reasons why languages vary in the way they do.

We begin by addressing a fundamental question of why there is linguistic diversity at all, and suggest that languages diversify in part because they are adaptations to different human environments. Next, we describe prior work showing that it is possible to account for some specific aspects of linguistic diversity by considering the socio-demographic 'niches' in which languages are used. On this view, languages adapt over time to optimize learnability and information-transmission within specific niches. This perspective is largely in line with that proposed by other contributors to this volume, particularly the work of Trudgill, and in the analyses of Burridge, Palmer, Stebbins, and Tadmor.

2. Why are there so many languages?

According to the story of the Tower of Babel, there was a time when all humans spoke a single language. A hubristic attempt to build a tower to the heavens led to God jumbling human languages (*Babel* comes from the Hebrew *balal*, to jumble). It is instructive to ask why there should be such a story at all. While existential wondering such as "where does the world come from?" (God made it) or "why do all humans look similar?" (made in God's image) seem a natural fit for religious texts, the question "why are there so many languages?" appears much more esoteric by comparison. One answer is that for most of human history languages were extraordinarily regional (a similar point is made by Trudgill, this volume).

2. We do not mean to suggest that cultures vary without limit, or that certain environments always produce particular cultural artefacts or institutions. The associations are always probabilistic. For example, it is less likely that a culture without access to clay develops a tradition of pottery, or that new types of sailing technology are invented in a culture that is landlocked.

From one settlement, one would need to walk a long way to encounter humans with obvious physical (racial/ethnic) differences. In comparison, in most places in the world the distance to the nearest language would have been quite short. Even at present, half of the world's languages have fewer than 7,000 speakers, and half are spoken over an area smaller then Luxembourg (Ethnologue, Gordon, 2005). As a result, people would be frequently exposed to individuals who looked very much like them, and yet spoke different languages, leading them to wonder "why?" Strikingly, we still do not have a clear answer. Explanations of linguistic diversity, both at the dialect and language level, have focused on drift. For example, Sapir (1921) writes:

> […] dialects arise not because of the mere fact of individual variation, but because two or more groups of individuals have become sufficiently disconnected to drift apart, or [drift] independently, instead of together. So long as they keep strictly together, no amount of individual variation would lead to the formation of dialects. In practice, of course, no language can be spread over a vast territory or even over a considerable area without showing dialectic variations, for it is impossible to keep a large population from segregating itself into local groups, the language of each of which tends to drift independently. (Sapir, 1921, p. 161)

Linguistic drift arising from both synchronic and diachronic processes is undoubtedly important in understanding the diversification of languages and geographic clustering (so-called areal patterns). But drift may not be the sole driver of linguistic diversity. Consider an analogous argument that drift is the source of biological variation. We can easily apply Sapir's analysis to, for example, a colony of finches. As the initial finch group splinters, the members of each subgroup will be more likely to mate with one another and, over time, the two groups will drift further apart genetically, eventually producing different species. But such an account leaves out a critical element: adaptation. An account of biological diversity that excludes adaptation cannot explain why, compared to the ancestral species, some finch species should come to have wider beaks, while others, longer beaks. Thus, the divergence of the groups is due not just to assortative mating, but also to the groups being subjected to different selective pressures. Even populations that remain in close proximity can rapidly diverge if their members come to occupy distinct niches that place an adaptive pressure on some trait, e.g. beak shape or foraging strategy. Indeed, the Galapagos finches initially studied by Darwin occupied small and often overlapping territories (see Weiner, 1995 for a book-length account of the fascinating research on Darwin's finches).

Thus, our ability to explain why a particular animal has the features it does clearly requires a consideration of the environment in which (and in a sense, *for*

which) it has evolved.[3] Here, we take this argument into the domain of languages. Just as with a beak of a particular shape, a particular grammar can be viewed as an adaptation to a particular environment.

3. How different are languages, really?

Before attempting to answer the question of what environments shape languages and how they might do so, it is worth considering the more fundamental question of whether languages really are different from each other in interesting ways. After all, in order for some languages or language variants to be preferentially selected, there must be variability from which to select.

Although the notion that languages differ at least on the surface is not in dispute, in some quarters it has been fashionable to assume that such variability is illusory and that its study detracts from the 'real' goal of understanding the deep structure of language. Such a deep characterization of language is often taken to be the generative model on which all languages are based (i.e. Universal Grammar). For example, Pinker (1994) writes:

> According to Chomsky, a visiting Martian scientist would surely conclude that aside from their mutually unintelligible vocabularies, Earthlings speak a single language. (Pinker, 1994, p. 232)

It is true that all languages share certain design principles such as compositionality and symbolic reference that make them, as a group, distinct from other forms of communication (both non-human animal communication and nonverbal human communication). Insofar as there are universal design features that separate human language from other communication systems, studying these features (e.g. symbolic reference, compositionality) (Deacon, 1997; Hockett, 1966) involves delving into the question of origins – questions that the Chomskyan research program has avoided, for the most part.[4]

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3. Evolution, of course, has no foresight. To say that a phenotype evolved for something is simply to say that the underlying genotype is more likely to be copied and, as a result, the phenotype becomes more prevalent in the population.

4. Consider a conclusion analogous to that reached by Chomsky's visiting Martian: "all life on earth is just variation on a Universal Grammar of DNA; differences among species are just dialects of DNA." At a high-enough level of abstraction, this is true. What would a scientist who is interested in this level of analysis study? Presumably, they might be interested in addressing questions about the origin of DNA, its stability in various chemical environments,

Claiming that "Earthlings speak a single language" is a bit like saying that there is only one kind of bird; that apart from different colours and sizes, and shapes, and so on, all birds are the same. It may indeed be useful to distinguish between animals that are birds and those that are not and we can fruitfully ask what is true of *all* birds. But surely it is at least equally sensible to ask why some birds eat fish and others eat insects and what characteristics make a bird suitable for one type of diet versus another, as well as why some parts of the world have many different species of birds and others have few. If we examine languages at a similar level of analysis, how substantial are differences between languages?

Judging by the difficulties that linguists have had in constructing even short lists of true linguistic universals (Evans & Levinson, 2009), the differences appear to be substantial. To give just a few examples: while some languages have rich inflectional and derivational systems of affixes, other languages appear to have little to none (e.g. Vietnamese; Thompson, 1987). Languages vary greatly in the depth of recursion they employ (whether one takes at face value Everett's (2005, 2009) claim that Pirahã lacks recursion entirely, one cannot dismiss the fact that recursion depth differs substantially between languages, e.g. Evans, 2003; Mithun, 1984). Although controversial, it has even been suggested that what were thought of as the fundamental building blocks of language: nouns, verbs, adjectives, and adverbs, are not universal as evidenced by languages such as Straits Salish (Jelinek & Demers, 1994) where the boundaries blur, mirroring a Borgesian fiction:

> […] there are no nouns but only impersonal verbs, modified by monosyllabic suffixes or prefixes[s] [F]or example, there is nothing equivalent to our word 'moon', but there is a verb that for us would be 'to moonrise' or 'to moon'. 'The moon rose over the river' would be 'Hlör u fang axaxaxas mlö': […] 'Upward, behind the onstreaming, it mooned.' (Borges, 1964, p. 8)

Even in phonology – the part of language perhaps most obviously constrained by physical limitations on production and perception – there are substantial differences in phoneme inventory size, syllable complexity, stress patterns, etc. (see Maddieson, Bhattacharya, Smith, & Croft, 2011, to get a sense of differences in consonant inventories and their world-wide distributions). To be sure, there are numerous constraints on cross-linguistic phonological variation. However, here too, the focus traditionally has been on phonology-internal factors rather than on

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properties of its replication, etc. The Chomskyan tradition, however, attempts to analyse language at this most abstract level while simultaneously rejecting as irrelevant both the origins of language and its functions. One would be forgiven for thinking that the relevance of what remains is hard to grasp.

understanding precisely how vocal production and speech perception shape phonological systems, or understanding the constraints that different environments may place on the functional properties of phonology, such as sound transmission through various mediums (see Ember & Ember, 2007 for some intriguing observations and speculations). For example, is it simply a coincidence that *whistled languages* such as Silbo Gomero (e.g. Meyer, 2004) tend to occur in environments that call for a way to communicate across large or difficult to traverse areas? Or do such phonological systems comprise an adaptation to the environment, a solution to a particular problem?

In summary, despite all languages having certain common design features (largely, those that distinguish language from other communication systems) at a level of analysis that examines grammars and lexicalization systems of specific languages, analyses have failed to find support for absolute universals. As put by Levinson, "[t]here is no sense of 'broad' under which 'the grammars and lexicons of all languages are broadly similar.' If there were, linguists could produce a huge range of absolute linguistic universals, but they cannot do so" (Levinson, 2003, p. 28). The rule seems to be constrained diversity, not universality.

3.1 Simulating the role of drift and selection pressures in linguistic diversity

Before we present further evidence for this perspective, we showcase a very simple simulation that implements the basic idea of languages adapting to their environments. So far we have suggested that linguistic diversity is produced by drift and selection, acting together. To illustrate more directly the role of selection pressures on linguistic diversity, we designed an agent-based simulation intended to serve as a simple existence proof. Agent-based simulations have been used in various contexts to demonstrate that verbalized theories play out in the manner that we expect, in idealized but computationally-implemented simulations. The simulation allows us to examine how the resulting communication systems change as a function of drift and selection pressure. In this admittedly idealized and simplistic simulation, we find that even a small amount of selective pressure acting on communication systems can drastically impact the amount of diversity that results.

In our simulations, as in many others, languages (i.e. grammars) are often defined as feature vectors (e.g. Chater, Reali, & Christiansen, 2009) and language change is quantified as changes to the values of these feature vectors (e.g. Nowak, Komarova, & Niyogi, 2001). Here, we defined language grammars as existing on just two dimensions, with each dimension taking on a real value between 0 and 1. Thus, each language L is defined as a two-element feature vector, (f_1, f_2). Each speaker/comprehender (agent, A) is defined as a pair of vectors, one corresponding to a particular value of the two-feature language spoken by that agent, and one

corresponding to the agent's physical location in a simulated terrain, defined by a 100×100 square map: $A = \{(x, y), (f_1, f_2)\}$.[5]

We initialized the simulation by starting 50 agents in the centre (location $x = 50$, $y = 50$) and then diffuse according to a set of migration rules. All agents at the beginning spoke the same language, $L_{original} = (.5, .5)$, in accord with the assumption of monogenesis of human language.

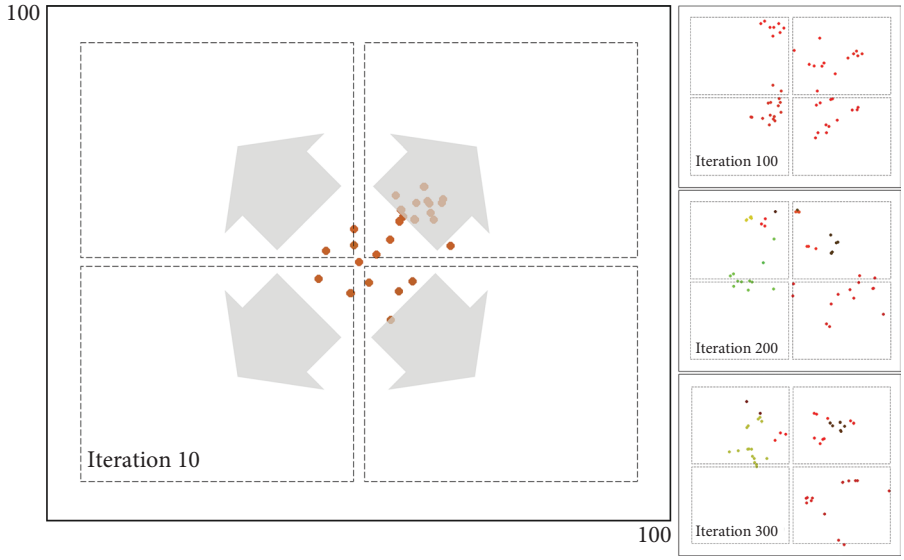

Figure 1. Left panel: A 100×100 grid traversed by 50 agents. Early in a simulation run (e.g. iteration 10), the agents are still near their origin, and their languages are relatively similar. Right panels: As the simulation proceeds, languages drift apart. The dotted lines demarcate four quadrants with different selection pressures (simulation 2). For example, the top-right quadrant of the grid, favoured drift towards higher f_1 values; the lower right quadrant favoured lower values of f_2. The other two regions were given the remaining selection possibilities (low f_1 value, high f_2 value). Colour is determined by the f_1 and f_2 values: different colours show the formation of "dialects."

On each iteration, we selected a random set of at most 5 agents that were within 10 units of each other and randomly moved them in any direction on the grid (maximum $\pm$ 20 steps). In addition, agents could communicate provided they could 'understand' one another. Agents were deemed to understand one other as

5. The editors correctly observed that our implementation assumes independence between grammatical features. This is a simplification; morphosyntactic features of real languages tend to be interdependent.

long as their languages differed by less than the 'talk threshold' – the Euclidean distance between their language vectors, here set to $\sqrt{2}/6$ (i.e. 17% of maximum distance; in reality, of course 'understanding' is not an all-or-none phenomenon). Finally, we also used language differences to decide migration patterns. We added the constraint such that agents only migrate together if they have languages within a distance of $\sqrt{2}/3$ (i.e. 33% of the maximum linguistic difference). This constraint implements the idea that agents in the same region of the landscape who speak the same language are a social group.

We also implemented a notion of linguistic 'conformity' – talk like the others talk (Keller, 1994). To this end, agents changed their language to be more similar to each other when they spoke. To implement this, each time agents communicated, they shifted their languages towards the mean language between them (using a simplifying assumption of symmetric social roles). Finally, drift was implemented as the proportion of the unit space (0–1) that an agent could shift its language up or down on each turn. As an example of the kinds of small changes or tweaks such drift corresponds to, consider the choice of using 'whom' vs. 'who' in the accusative, or the choice between the prescriptively correct 'between you and me' vs. the colloquial 'between you and I.' The magnitude of the drift parameter controlled the freedom the agents had to 'play' with language.

We ran the simulation for 500 iterations using 50 agents and explored a range of drift and selection parameters. At each iteration, one group of agents (maximum $N = 5$) was permitted to migrate on the 100 x 100 terrain. Also at each generation, all agents were permitted to "communicate" with a group of agents (maximum 10) that were within a 10-unit distance around it, and that had sufficiently similar languages (as described above).

The results from simulations varying the amount of drift (k, using drift value of $\pm\ kU(0,1)$) and selection-pressure are shown in Figure 2. Not surprisingly, drift has a large impact on language stability. When drift is very small (i.e. there is almost perfect language transmission from one generation to the next), the language fluctuates around its initial state of (.5, .5). When drift is increased to 5%, languages become wildly unstable, oscillating radically from one time-step to the next (a situation that would prohibit effective communication). With an intermediate amount of drift (1%–3%), the languages diversify while maintaining stability.

We next examined the effects of selection pressure on linguistic diversity. Selection pressure was implemented by differential copying of languages that happened to be most adaptive to the environment in which the language happened to find itself. To simulate different environments, we divided the 100×100 grid into four quadrants. In each quadrant, languages with particular feature-values were 'favored'. For example, in quadrant 1 (top right), languages which happen to have high values on feature 1 would be favored, with no selection pressure applied

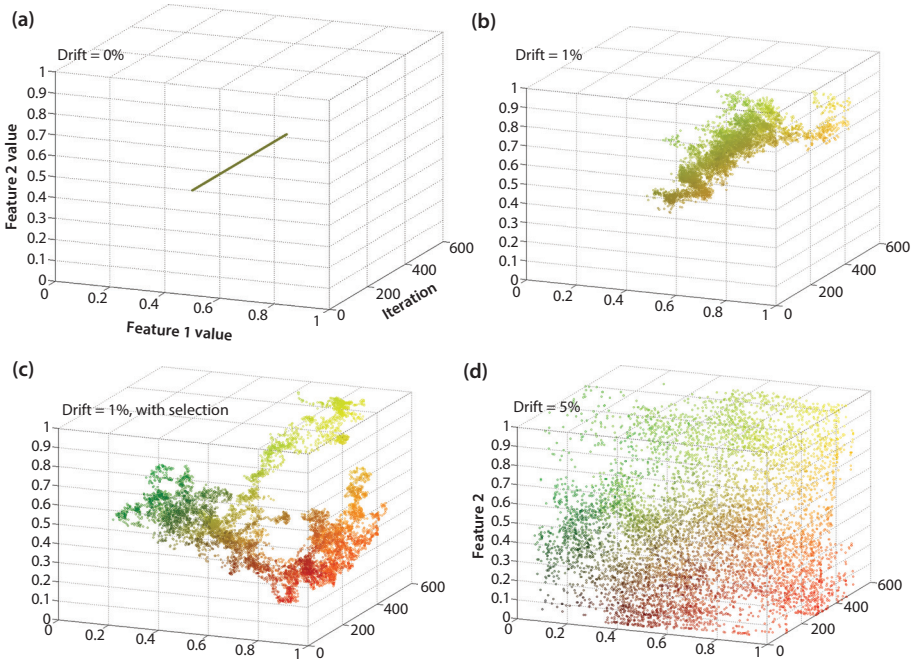

Figure 2. Example runs of the simulation under different parameter values. Colours are only for illustration, and are coded using the feature values, facilitating the observation of dialect formation over time (iterations). See text for details

to feature 2. The selection of particular language-variants was done by increasing the likelihood of agents imitating those using a more adaptive feature than a maladaptive or neutral one. Although we use the word *imitation*, the process should not be thought of as goal-driven. Imagine an environment in which certain phonemes are poorly transmitted, e.g. phonemes with high-frequency components in a tunnel with a T intersection (Imaizumi, Kunimatsu, & Isei, 2000). Individuals using those phonemes, all other things being equal, would be less likely to be imitated than those using alternate forms that are better transmitted.

The effects of selection can be seen in Figure 2 and Figure 3. In Figure 2, each point represents the language state of an agent A and its (f_1, f_2) vector, across time (iterations). Figure 2A shows that, when the simulation has no drift, the two language features stay fixed at their initial values. However, when some drift is added (a 1% perturbation during each interaction: Figure 2B), the languages can begin to explore the parameter space, and come to form agent 'dialects'. With too high a drift value (5% perturbation: Figure 2D), dialects cannot readily stabilize and languages fluctuate rapidly from iteration to iteration. Things change substantially when the "environment" creates diverse selection pressures. A selection pressure allows

languages to rapidly diversify into dialects, even with minimal drift (Figure 2C). Holding drift rate constant, even a small selection pressure allowed the space of possibilities to be explored more quickly, with the 'languages' slowly converging on patterns better adapted to particular regions of the grid (Figure 3).

Allowing languages to adapt to the environment rather than just change as a function of drift has a profound effect on the level and type of linguistic diversity. On this account, patterns of linguistic diversity can be explained not only in terms of shared history and common descent, but in terms of environmental pressures: Languages spoken in similar social and ecological environments may become more similar as they adapt to common pressures. Even if the adaptive pressure is small, it can have drastic long-term effects on patterns of linguistic diversity. Our simulation shows how linguistic diversity can arise when drift combines with even a pinch of selection. Although highly idealized – the grammar only has two independent grammatical features and assumes symmetric communication – we view this simulation as a starting point for exploring questions concerning the sources for linguistic diversity.

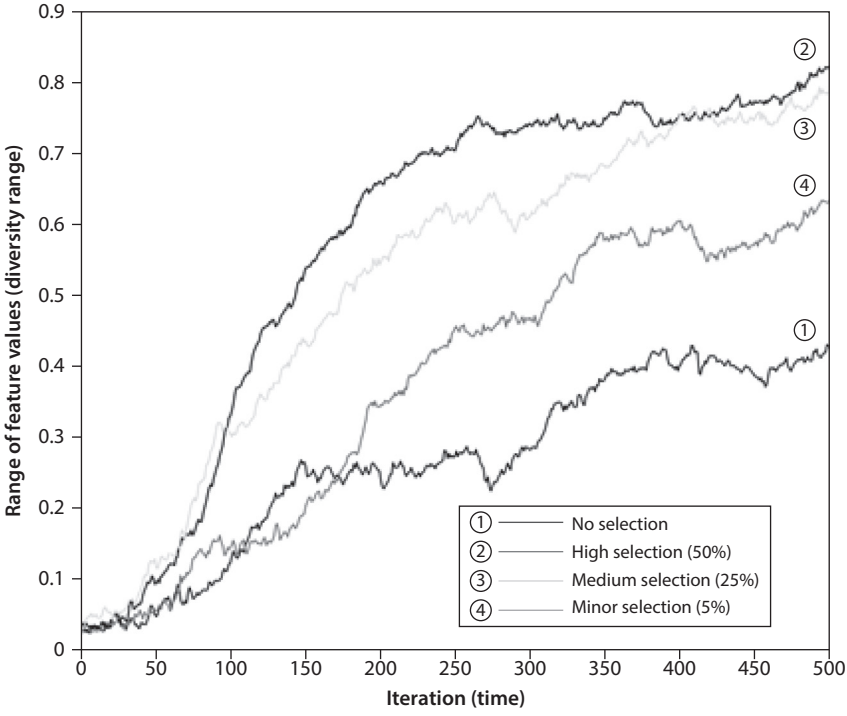

Figure 3. The results of four different runs using 1% drift with varying selection rates. The y-axis shows the average range in f_1 and f_2 across 5 runs of the simulation. Higher scores indicate greater linguistic diversity

4. The role of drift and selection in explaining linguistic diversity

Let us return to the biologist faced with observing differences in beak shape between species of finches. After describing and quantifying the variation, a logical next step would be to understand what factors may be responsible for the observed differences. An obvious place to look in the case of beak shape would be the animal's diet and availability of food sources that are more easily or more difficult to access using various beak shapes. Once the mapping between beaks and diet is determined, one can look at how changes in availability of food impact the mortality and reproduction rates of individuals with varying beak shapes across and within a species – direct evidence of a selective pressure on beak shape. In other words, beak shapes represent evolutionary adaptations to specific ecological environments. As we elaborate in more detail below, we believe that substantial progress in understanding linguistic variability can be made by applying an analogous approach to language and treating different languages as adaptations to different environments.[6]

The idea that there may be some systematic relationship between language and aspects of the environment, particularly the social, cultural, and technological aspects of the environment, is not a new one. In fact, speculations on the connections between particular grammars and culture appear were so common (see Enfield, 2004; Perkins, 1992 for discussion), that in his 1921 book, Sapir admonished all attempts to link language types to culture:

> It is difficult to see what particular causal relations may be expected to subsist between a selected inventory of experience [and] the particular manner in which the society expresses all experience. (Sapir, 1921, p. 233)

> [A]ll attempts to connect particular types of linguistic morphology with certain correlated stages of cultural development are vain. Rightly understood, such correlations are rubbish […] Both simple and complex types of language of an indefinite number of varieties may be found spoken at any desired level of cultural advance. When it comes to linguistic form, Plato walks with the Macedonian swineherd, Confucius with the head-hunting savage of Assam.
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> (Sapir, 1921, p. 234)

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6. It is important to note that there is no requirement for every observed trait to be functional or predictable from some aspect of the environment. Indeed, conditional universals of the form "If a language has property A, it most likely has property B," are a prime example of how a selective force acting on property A may also affect property B (which in turn may become exapted for other functions).

At the same time, Sapir also noticed that language changes were not random, but exhibited what he referred to as the "drift to the invariable word," noting for example that "striving for a simple, unnuanced correspondence between idea and word that [is] very strong in English" (Sapir, 1921, p. 180). Sapir believed that these changes were due to forces internal to language: "Language moves down time in a current of its own making. It has a drift" (p. 160) and that while the lexicon of a language is naturally shaped by the needs of its speakers, "its line of variation, its drift, runs inexorably in the channel ordained for it by its historic antecedents" (p. 232).

The apparent directionality of language change was also described by Jespersen, who made similar observations of language apparently tending to become, over time, more analytic, but, unlike Sapir, Jespersen saw in these changes a kind of progress: "[There is a] progressive tendency from inseparable irregular conglomerations to freely and regularly combinable short elements," arguing that in "modern" languages, words are shorter, "thus involving less muscular exertion and requiring less time for their enunciation", their formation (i.e. morphology) and syntactic use (i.e. recombination) "present fewer irregularities" and "[t]he clumsy repetitions known under the name of concord have become superfluous" (Jespersen, 1922, p. 364). For a more elaborate discussion of this so-called principle of economy, see Croft (2002).

As we shall see (and as noted by Trudgill, this volume, and Trudgill, 1988, 1989, 1993, 2001a; as well as by Christiansen & Chater, 2008; Dahl, 2004; McWhorter, 2001; Nettle, 1996, 1998a, 1998b; Perkins, 1992; Wray & Grace, 2007), there really is something to this observation. But in ascribing progress to these apparently directional language changes, Jespersen makes the same mistake as someone who, on observing the apparent advantage of the giraffe's long neck, concludes that zebras, antelopes, and the decidedly short-necked gnus, are all at different stages of progress toward girraffean necks. The proper analysis, of course, is that long necks are an adaptation to a particular environment – a niche. Just as we can explain the emergence of and changes in physical traits as responses to selective pressures from the environment, we can conceive of culturally-transmitted traits (of which language is but one) as reflecting adaptations to particular niches. The philosopher Ernst Cassirer expressed a similar idea, writing:

> Every classification is directed and dictated by special needs, and it is clear that these needs vary according to the different conditions of man's social and cultural life […] Languages vary with the functions they fulfil in the cultures in which they are spoken. (Cassirer, 1962, p. 136)

The use of language like 'special needs' smells of teleology, but this should not detract from the more general point of an adaptive fit between the language and

the environment in which it is used. One clear case comes from the use of language to pick out entities worth communicating about. Many words, concrete nouns in particular, name specific objects, and insofar as there are cross-cultural differences in what needs to be named, the lexicon adapts accordingly. But what of grammatical factors such as verb agreement, cases, and other features that apparently serve purely linguistic functions? What 'special need' might these fulfil and what possible conditions of 'man's social and cultural life' might vary to as to make some of these linguistic features variously adaptive in different environments?[7]

This is not an easy question. When faced with a question of this form in the biological domain, we are aided by a large knowledge base, compiled through observation and theorizing, about functions conferred by various phenotypes. We see birds using their beaks for eating, and we make the reasonable assumption that differences in beak shape may have something to do with obtaining food. We observe leopards hunt and theorize that their coat markings are an adaptation to avoid detection by prey. In inquiring about the functional significance of specific linguistic features, we know far less. What are inflectional evidentials *for*? Person agreement? Complex hierarchies of demonstratives?[8]

Rather than focusing on explaining why some languages have specific features such as complex person agreement, while others do not, one can ask whether particular *types*[9] of languages are more likely to be found in one environment or another. What aspects of environment, of Cassirer's 'social and cultural life' are the important ones? Might it matter, for example, if a language is spoken by a thousand versus a million speakers? In an artefact-rich or largely natural environment? In a *society of intimates* or a *society of strangers*? If it borders many languages or is geographically isolated?

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7. See LaPolla, this volume, for one suggestion.

8. A broad objection to this idea on the grounds that it is impossible to explain language functionally because it is some type of perfect and non-functional artefact (Brody, 1998; Lasnik, 2002; Piatelli-Palmarini & Uriagereka, 2004) makes little sense to us and we cannot think of any other domain in which an analogous proposition would be seriously entertained.

9. We focus on types because given how little we still know about the functional role of specific features – we are only now starting to systematically catalog and quantify linguistic variation on a large scale (Dryer & Haspelmath, 2011) – it may be premature to theorize about the functions of any specific feature and a more productive approach may be one that focuses on broader distinctions as detailed below.

5. The fit of languages to their environments: The importance of learning mechanisms

A useful starting place for understanding the fit between languages and their environments is the self-evident but often overlooked observation that languages need to be learnable (Christiansen & Chater, 2008; Deacon, 1997). By definition, an unlearnable language cannot exist. But while all natural languages are constrained by what can be learned by infants, only some languages are additionally constrained by what can be learned by adults. Insofar as children and adults differ in the kinds of linguistic devices they learn most effectively, an immediate prediction is that languages with a larger number of non-native speakers and ones in which people commonly talk to strangers (the so-called 'exoteric' niche (Thurston, 1989; Wray & Grace, 2007), analogous to Trudgill's use of the term *societies of strangers*; see this volume) will come to have simpler morphological paradigms. Trudgill articulated a version of this hypothesis in perhaps the clearest way:

> Just as complexity increases through time, and survives as the result of the amazing language learning abilities of the human child, so complexity disappears as a result of the lousy language-learning abilities of the human adult. Adult language contact means adult language learning and adult language learning means simplification, most obviously manifested in a loss of redundancy and irregularity and an increase in transparency. (Trudgill, 2001a, p. 372)

Similar arguments, focusing on the role of the language population on morphological complexity, have also been discussed by McWhorter (2001, 2002, 2007), Wray & Grace (2007), and a number of contributors to Sampson, Gil, & Trudgill (2009).

A strong test of this hypothesis on a large scale, however, only became possible with the publication of large corpora of grammatical features (e.g. Dryer & Haspelmath, 2011), which allowed us to examine whether morphological complexity is actually predicted by factors related to exotericity, namely the number of speakers. It turns out that simply knowing how many people speak a given language, or how widely a language is spoken around the world (in km^2), we could predict, sometimes with very high certainty, some of its grammatical features. For example, we found that languages with many speakers tended to: (1) be less synthetic or fusional in their overall structure, (2) have simpler noun and verb agreement systems, (3) have simpler overall verb morphology, (4) have fewer nominal cases, (5) lack inflectional evidentials, future tense, and aspect markers. Population, as well as geographic spread and number of bordering languages – the three proxy factors we used to quantify exotericity – predicted over 20 grammatical factors related to morphology (controlling for language family and geography and

using Monte Carlo analyses to deal with Galton's problem of non-independent sampling; Lupyan & Dale, 2010). Overall, our results showed that given the choice of expressing a certain semantic distinction using morphological or lexical means, exotericity was positively correlated with lexical strategies and negatively correlated with morphological encoding of these distinctions. We framed the results in terms of the *Linguistic Niche Hypothesis* (Lupyan & Dale, 2010), arguing that they are indicative of languages evolving to fit the learning constraints of their learners. As a language spreads more widely, and is learned by more adult non-native speakers, its morphological structure tends to simplify. This is the very process Trudgill seems to envision taking place:

> Adults [learners …] necessarily subject new languages that they are learning to the process of pidginization… an increase in transparency, by which is meant an increase in forms such as *eye-doctor* as opposed to *optician,* and *did* instead of *went*. Imperfect learning, that is, leads to the removal of irregular and non-transparent forms which naturally cause problems of memory load for adult learners, and to loss of redundant features. This can in turn lead to an often dramatic increase in analytic over synthetic structures. (Trudgill, 2001b, p. 66)

Our findings, across over 2,000 languages, suggest that such a process is actually at work. As a further test of the hypothesis that exotericity, particularly adult learning, increases transparency, consider differences between American and British English. American English is used in a considerably more exoteric setting, as measured by, for instance, the relative proportions of non-native speakers.[10] According to Ethnologue (Gordon, 2005), about 20% of US-English speakers are non-native English speakers, versus about 5% British English speakers in the UK (though the latter number is rapidly increasing). We would therefore expect American English to show a preference for more regular/transparent forms. Following Trudgill's example, the top panel of Figure 4 compares the more transparent *eye-doctor* to the more synthetic/derivational form *optician* in American and British English (Corpus of Global Web-Based English; Davies, 2013).[11]

One may wonder if such differences are a symptom of British English being simply more conservative in comparison to American English, perhaps owing to its smaller speaking population. Such an explanation, however, could not account for why British English has apparently been *more* willing than American English

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10. It may be objected that it was British rather than American English that was spread around the world in colonial times. This is true, but its learning by non-native speakers, and hence the changes which we hypothesize to be caused by this learning, were largely outside the boundaries of England proper.

11. The more appropriate comparison to *eye doctor* may be *optometrist* or *ophthalmologist*.

to replace the more regular form of *lighted* with the morphologically irregular *lit* (Figure 4 bottom). Compared to British English, American English shows a resistance to the irregularization trend that is replacing *lighted* with *lit*. As shown in Figure 5, while *lit* overtook *lighted* in 1912 in UK English, it took until 1950 for *lit* to overtake *lighted* in US English; see Dale & Lupyan (2012) for further discussion. A common explanation for both patterns is that American English has a stronger affinity for simpler morphology and greater form-to-meaning transparency.

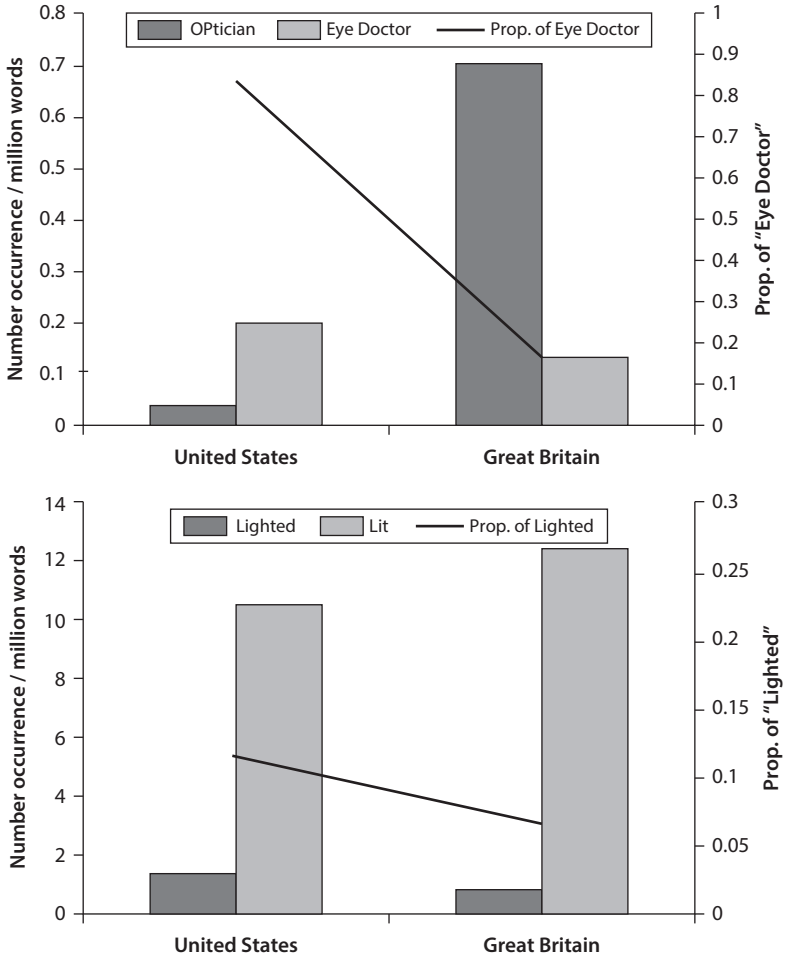

Figure 4. Number of occurrences per million of *optician* and *eye-doctor* (top) and *lighted* and *lit* (bottom) in American and British English. Line shows the proportion of the more analytic/regular form

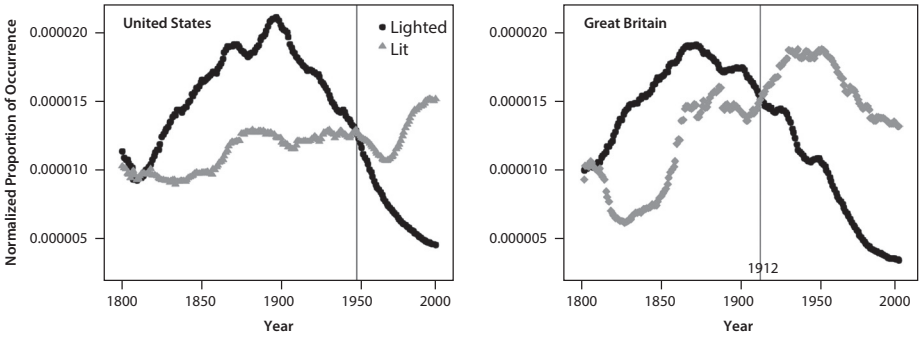

Figure 5. Google N-Gram analysis of the trajectory of *lighted* and *lit* for the US (left) and UK (right). US English shows a resistance to the irregularization of the verb

The above analyses, although suggestive, are clearly preliminary. More rigorous work is needed to determine the degree to which there is a systematic bias in American English for more transparent form-to-meaning mapping, and the degree to which the results reflect more universal trends. For instance, one might make the opposite prediction for Quebecois French as compared to French in France insofar as Quebecois became more insulated from influences of outsiders. Beyond the specifics, however, our larger claim is that differences between American and British English can be understood in part as the consequence of languages – the varieties of English, French, etc. – adapting to slightly different niches.

If one assumes that children are better learners of opaque form-to-meaning mappings than adults, it is easy to see how non-native speakers in a language act as a kind of bottleneck. But what may be less obvious is how the presence of non-native speakers can impact the native-speaking population. To understand how this works, we recall that languages need to be learned by their speakers (we deliberately avoid the term *acquire* commonly used when referring to language learning in infancy because it implies that early language learning is not really learning). The exact form of a language a child will learn depends strongly on the input. If non-native speakers speak differently from native speakers, then their input to children may affect – if only slightly – the language the child goes on to learn. Situations in which the child's language models are similar to those of non-native speakers may be quite common. For example, in a survey of 188 individuals in Senegal who listed Bambara as their native language, Bambara was the father's native language in 16%, the mother's in 19%, the native language of both parents in 26%, and the native language of neither parent in 39% (Calvet, 2006). Although children are learning Bambara from a young age and are, in theory, fully capable of learning whatever morphology it possesses, in such a

multilingual environment, much of the language Bambara children hear may come from non-native (or non-fully native) speakers. Thus, whatever aspects of Bambara were difficult for the parents to learn would be more likely to be passed on to the offspring in a revised form.[12]

To investigate further the influence of even a small amount of exposure to non-native speakers, Dale & Lupyan (2012) elicited acceptability ratings of overregularized sentences such as *He speeded down the road* and *They sneaked around* from 95 native American English speakers from around the country. The results showed that the degree of acceptability of such sentences (partialing out several factors like level of education) was predicted by the amount of childhood exposure to non-native English speakers (derived from self-report and US Census records based on the proportion of non-native speakers in the US state where they grew up). People who reported hearing more non-native English were more tolerant of over-regularized forms. In the same paper, we describe a series of agent-based simulations that show how even a small bias against complex morphology can impact the level of morphological specification that a language comes to possess.

An important caveat to our proposal is that languages spoken in similar social and ecological environments may become more similar as they adapt to common pressures while those spoken in varying environments may diverge as they adapt to these environments. Some regions of the world such as Papua New Guinea are hotspots of linguistic diversity. Given the small geographic extent and relative similarities in cultural practices within such regions, one may wonder why linguistic diversity should be as high as it is. As pointed out by Nettle (1998b), these hotspots of linguistic diversity tend to be correlated with long growing seasons and ecological stability, meaning that small societies can be more self-sufficient with less need for trade, which contributes to language diversification via drift – a non-adaptive explanation process. An additional source of variability, however, may owe itself to active diversification. Language is, of course, a strikingly powerful marker of group identity; even within a language, accented speech in some cases serves as a marker of affiliation more than physical appearance (Kinzler, Shutts, DeJesus, & Spelke, 2009). It has been noted that this may be especially important in small societies. For example, Crowley and Bowern cite statements

12. We do not mean to suggest that infants simply copy what they hear. All language learners generalize beyond their input. But if, for example, a particular morphological distinction is simply absent from the input, then it is unlikely that the learner is going to reinvent it on their own.

from the Sepik region of Papua New Guinea like "It wouldn't be any good if we all spoke the same. We like to know where people come from" (2010, pp. 14–15). Put in an adaptationist framework, in cultures in which it is especially important to mark group identity (e.g. due to an especially strict in-group bias), language diversification may play an important role as a shibboleth. Although this mechanism is distinct from the learnability biases that we have focused on, it too suggests that language diversification cannot be explained through random drift alone.

6. The child-adult learnability trade-off

We have argued that while all languages are necessarily constrained by what can be learned by infants, only some – the languages occupying the more exoteric niche – are further constrained by the limitations of adult language learning. Morphology, being one domain in which adults struggle, thus appears to simplify in languages constrained to be learnable by adults. But why does complex morphology arise in the first place? It has often been noted that languages are more complex than what is apparently needed for communication (e.g. Premack, 1986), and as Gil (2009) argues, the extra complexity does not seem necessary given how much can be accomplished with languages lacking these "baroque accretions" (see McWhorter, 2001 for discussion). From a linguistic-niche perspective, one possible answer to this puzzle is that complex surface morphology and paradigms that present difficulties for the adult learner actually *benefit* child learners. Consider, for example what Jespersen referred to as "clumsy repetitions known under the name of concord", more familiarly called agreement. Any system of agreement (e.g. between nouns and verbs, nouns and adjectives) is redundant in the sense that if the noun makes it clear who the subject of the sentence is, marking it additionally on the verb becomes unnecessary. But perhaps such repetition and the redundancy it imparts provide learning benefits to children. While agreement (as well as grammatical gender, complex demonstratives, morphologically encoded aspect, evidentiality, etc.) can pose challenges for adult L2 learners, perhaps it can *facilitate* language learning by children by providing them with additional cues helping to ground the linguistic stream to the goings-on in the environment. One rationale for this proposal is that in comparison to adults who can deploy powerful pragmatics, theory-of-mind, and general world knowledge to make sense of partially ambiguous utterances, children do not yet have these mechanisms at their disposal. Thus, encoding aspect, gender, evidentiality, etc. grammatically (with its

corresponding increase in redundancy) may baffle the adult, but be beneficial to the child learner.[13]

An immediate objection to the idea that richly inflected languages are better adapted to child learners is that it seems to suggest that children ought to be better at learning morphologically complex (and more opaque) languages than simple languages such as English. There is indeed some evidence of differences in learning rates across languages (e.g. Slobin & Bever, 1982), and some evidence of faster learning by children of more complex inflectional systems. For example, Devescovi et al. (2005) observed that Italian children require fewer words to extrapolate grammatical regularities of Italian compared to children learning English, a difference the authors ascribed to the richer inflectional system of Italian, which provides the children with increased learning opportunities. However, such cross-linguistic differences in language learning appear to be fairly minor. Much more substantial cross-linguistic/cross-cultural differences can be found in the amount of language directed at prelinguistic children (e.g. Johnston & Wong, 2002; Richman, Miller, & LeVine, 1992; Tamis-LeMonda, Song, Leavell, Kahana-Kalman, & Yoshikawa, 2012; Vogt & Mastin, 2013). An intriguing possibility is that such differences interact with the grammar of the language being learned by the children. If more richly inflected (and hence more redundant) languages are especially well adapted for child learning, then perhaps they can be learned with less input. As a language becomes exposed to the learning constraints of adults and loses some of the inflectional richness (and with it, redundancy), children require more input to learn it. There is now considerable evidence showing how sensitive English-learning children are to reduction in input (Hart & Risley, 1995; Hoff, 2003; Hurtado, Marchman, & Fernald, 2008; Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002). Direct comparisons of input sensitivity between languages – needed to test the outlined hypothesis – are lacking at present.

To make more concrete the idea of languages adapting to the constraints of child learning more, consider two further examples: (1) There is clear evidence that processing sentences with deeper embeddings requires greater working memory (Lewis, 1996) which, in the case of young children, is in shorter supply (e.g. Gathercole, Pickering, Ambridge, & Wearing, 2004). This may produce interesting trade-offs between morphological and syntactic complexity. Insofar as

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13. As a demonstration that languages spoken in more esoteric niches are indeed more redundant, Lupyan & Dale (2010) quantified informational redundancy in terms of the Huffman codes which can be approximated by zipping a text file. Redundancy is proportional to the degree to which the file can be compressed. We found that, indeed, languages spoken by fewer people (typically those with few non-native speakers) were considerably more compressible, i.e. had greater redundancy.

morphological complexity tends to allow for simpler syntax (particularly in the case of syntactic embedding, see Evans & Levinson, 2009), one can ask whether languages constrained only by child learning may trend toward syntactic structures with lower working memory requirements. The results of Lupyan & Dale (2010) are consistent with this possibility, but more targeted investigations are necessary before making stronger conclusions. (2) We have discussed inflectional systems in very broad strokes, speaking of richly inflected languages versus ones with little inflection, but of course there is substantial variability in the form those inflections take. One difference is whether the inflections take the form of suffixes or prefixes. According to WALS, there are far more languages that are biased (moderate to strong) for inflectional suffixing (529 languages from 87 language families) compared to prefixing (152 languages from 31 language families). Based on these data, one could conclude that suffixation is, in some way, more natural. However, if we look at the demographics of the languages that use suffixation versus prefixation, a different picture emerges. Of the 18 language families that have both prefixing and suffixing languages according to WALS, the suffixing languages have a mean population of about 3000 speakers, and the prefixing languages about 6500 speakers Languages that in our view are adapted for child learning may favour suffixes, while those that have been more strongly shaped by adult learning may favour prefixes[14] Indeed, there is some evidence that suffixes are easier to learn for infants than prefixes (Kuczaj, 1979; Slobin, 1979, 1985), and there is some indication from experimental studies that prefixes are easier to learn for adults compared to suffixes (Frigo & McDonald, 1998; MacWhinney, 1983; St. Clair, Monaghan, & Ramscar, 2009). A similar mismatch between 'naturalness' according to number of languages/language families demonstrating a given trait and language demographics is basic word order. Despite SOV being the most widespread word-order in terms of absolute number of languages and somewhat more prevalent in terms of number of language families, when examining the 16 language families that have both SOV and SVO languages we find that the mean population of SOV languages is about 16,000 and the mean population of SVO languages is bout 33,000. This pattern suggests that SVO languages may be favoured by adult learners.

In summary, although there now appears to be converging evidence for the connection between adult language learning and morphological simplification,

14. Indo-European languages are omitted from this analysis because they only have inflectional suffixing. One may wonder why, given the relative exotericity of Indo-European languages, they lack prefixing if it provides a learning benefit. Our uninformed guess is that this is a case of path dependence. Inflectional prefixes were outside the variation of the Indo-European language family and thus could not be selected.

the reasons for languages having complex morphological systems to begin with are more puzzling. We have argued that rather than being non-functional 'baroque accretions, complex morphological systems may play a role in facilitating language learning by children and are thus an adaptation to the esoteric niche. This proposal remains speculative and awaits more rigorous empirical tests.

7. Ecological constraints on language structures

In discussing the environment to which languages adapt we have focused on social and demographic factors, such as the effect of a language being constrained by child learners or a combination of child and adult learners. We have said little about the ways in which grammars may adapt to exogenous factors such as the physical environment in which the language is learned and used. Below, we consider several examples from the domain of spatial language.

Although all languages have ways of expressing the relative locations of objects or people, the precise means of doing so differs (Levinson & Wilkins, 2006). One source of such difference lies in the system of demonstratives, terms such as *this*, *that*, *here*, and *there*. In some languages, like English, the demonstrative systems are relatively sparse and underdetermined. To make sense of an expression such as *I am here*, one needs to know quite precisely the context of the utterance. Does the speaker mean *here* in the city? *Here* in the building? *Here* in the office, *here* at the restaurant? Of course, one can optionally add this information, but, nothing about the word *here* specifies where *here* is. Such systems contrast with systems that require speakers to encode relative location much more precisely using demonstratives and other devices such as deictic adverbs (e.g. Denny, 1978, 1982; McWhorter, 2002 for a discussion of English as compared to other Germanic languages). To what degree may such differences reflect adaptations to different environments? Denny (1978) proposed that certain spatial systems seem particularly well-suited for describing relative locations in artefact-sparse environments, in which the familiar English system of demonstratives and deictic adverbs would appear to fail. In English, we regularly refer to regions of space with phrases such as *That one across the street* or *To the left of that mailbox*. But such expressions would be of limited use in an environment in which no such reference points exist. One solution is to centre the space on speakers and listeners instead. As Denny writes:

> [In] a natural environment of non-human spaces one way to relate space to human activity is to use deictic spatial concepts, to center space on the speaker or other participants. [In a man-made environment this is less necessary […] we can use non-deictic locatives (down the road, around the corner) which will relate space to human acts quite directly since the places mentioned are all artefacts designed to aid such acts. (Denny, 1978, p. 80)

Is the presence of complex demonstrative systems in some languages simply a coincidence? Or might they be seen as an example of a linguistic adaptations to particular ecology? No one, to our knowledge, has looked at relationships between ecologies and language structures. In a feasibility study, we used the Standard Cross Cultural Sample (SCCS; White, 2007), an ethnographic database of 186 cultures, to test the generality of Denny's (1978) observation inspired by the study of spatial terms in Eastern Eskimo. Without the ability to say things like *next to the mailbox*, the language is, on the present account, under a selective pressure to develop complex speaker- and listener-centred spatial terms (that are unnecessary in an object-rich environment). We undertook a preliminary analysis in which we combined the biome factor from SCCS (desert, tropics, tundra, etc.) with the number of spatial-term distinctions coded by WALS (because SCCS does not include information on specific languages, this analysis was done at the level of language families). Not only did languages spoken in the five biomes differ significantly in the complexity of demonstratives, but the languages spoken in the most sparse biome (tundra and taiga) had systems of demonstratives with reliably more remoteness distinctions compared to languages spoken in other biomes. These preliminary results hint at the wealth of possible patterns that may be found by larger-scale theoretically-guided analyses aiming to understand how particular language structures – morphological, syntactic, semantic, and phonological – interact with ecological influences. At the same time, however, one must be cautious in performing such analyses and recognize that most patterns of linguistic diversity will not lend themselves to simple explanation by ecological factors.

8. Conclusion

Our main claim is that it is impossible to understand why there are so many languages and why languages differ as they do without taking into account selective pressures that have operated and continue to operate on languages. These pressures can be both endogenous, such as cognitive limitations (which may differ quite drastically for child and adult language learners with consequences for languages with many versus few adult learners), and exogenous, such as ecological factors in which the language is used.

At present, we would characterize our state of knowledge in understanding what these pressures are, and how they operate, as minimal. However, we see exciting possibilities in research programs that combine descriptive linguistic datasets with anthropological data, ecological information, literature on child-language, and finally, studies that use artificial-language learning paradigms to study experimentally how languages are influenced by the cognitive constraints of the learner (e.g. Ellefson & Christiansen, 2000; Monaghan, Christiansen, & Fitneva, 2011;

St. Clair et al., 2009), and by ecological factors (e.g. Enfield, 2004; Nettle, 1998b). Progress can be further hastened by abandoning the assumption that all languages are 'broadly' similar and equally complex (see Evans & Levinson, 2009; Sampson et al., 2009 for discussion), and stressing the connections between diachronic and synchronic linguistic variation and socio-demographic variation, insofar as these connections can inform our understanding of how linguistic systems react to environmental challenges.

Most importantly, language – both the human capacity for language, and specific grammars – must be viewed as functional systems shaped by cultural evolution. There does not appear to be any reason for excluding language from functionalist approaches that are so useful in explaining other evolved traits.[15] A dictum of Dan Slobin's makes for an apt conclusion:

> The acquisition and development of any linguistic form or construction must be considered in the light of its 'functional load' within the language and speech community. (Slobin, 1997, p. 35)

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