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Opinion

Why Are There Different Languages? The Role of Adaptation in Linguistic Diversity

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Why are there different languages? A common explanation is that different languages arise from the gradual accumulation of random changes. Here, we argue that, beyond these random factors, linguistic differences, from sounds to grammars, may also reflect adaptations to different environments in which the languages are learned and used. The aspects of the environment that could shape language include the social, the physical, and the technological.

> Each split in the tribe made a new division and brought a new chief. Each migration brought different words and meanings. Thus the tribes slowly scattered; and thus the dialects, and even new languages, were formed. [1]

Why Are There Different Languages?

Along with questions about the origin of life and the universe, questions about the origin of language are so fundamental that they feature in the origin stories of many of the world's religions [1]. This status is well earned. Language vastly increases the ability to transmit information between individuals. It is the foundation of a cumulative cultural evolution [2,3] that allows us to perform mental and technological feats unthinkable to even our recent ancestors.

All languages share several basic design features, such as **productivity**, **categorical denotation**, and **compositionality** (see Glossary), which distinguish linguistic systems from both nonhuman communication systems and nonverbal human communication [4,5]. However, what also distinguishes language from other communication systems is the extent to which languages differ from one another. Although there are regional differences in the communication systems of some other animal species, few if any natural communication systems come close to the diversity we see in language. Our species speaks not one language or several dialects of one language, but thousands of distinct languages (Box 1).

Why does this diversity exist? Why do we not all speak one language? This question presents a challenge to language researchers regardless of their theoretical commitments. If languages are tightly constrained by innate machinery, why are languages not more similar to one another, much as facial expressions are similar from culture to culture (but see [6])? If languages emerge from general learning mechanisms and iterated cultural transmission [7,8], and if they all undergo the same processes of usage-based change, such as **grammaticalization** [9–12], why are languages so different and why are they not all converging to a common form?

Trends

It is commonly thought that humans speak different languages simply because the languages drifted apart due to the gradual accumulation of changes.

We challenge this assumption by reviewing evidence that language diversification may also occur as languages adapt to different environments. Social context, ecology, genetic factors, and communication technologies may act as pressures to which languages adapt and thereby diversify.

Aspects of language that promote its learning and effective use are likely to spread, but what is optimal for one environment may be suboptimal for another.

We conclude that linguistic adaptation should be included alongside language-internal conceptions of language change. Linguistic adaptation may help to explain why humans speak different languages and why linguistic differences can be partly predicted by the environment in which a language is learned and used.

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Box 1. How Different Are Languages, Really?

Chomsky famously invoked a Martian scientist who, on visiting Earth, 'might reasonably conclude that there is a single human language, with differences only at the margins' [88]. If this is true, then the very idea that languages adapt to their environments may appear misguided. So, how different are languages, really?

Within the lexicon, differences between languages range from the more obvious to the more surprising [89]. As might be expected, the vocabulary of a language is shaped by its environment and broader culture. Cultures with a need to communicate large and exact quantities have more-developed counting systems [90,91]. Languages spoken in colder climates are more likely to have dedicated words for snow and ice [92]. However, languages also differ in their degree of lexical encoding of domains universal to all humans. All people eat and drink, yet there are considerable differences in how these universal actions are lexicalized by different languages [93,94]. All people inhabit a common three-dimensional space, yet there are substantial differences in how different languages describe space and spatial relations [95,96]. Diversity is also observed in the lexicalization of body parts [97], kin relations [98,99], time [100,101], emotions [102,103], common actions [104,105], colors [106,107], and even basic geometric shapes [108,109]. Such variability is, of course, not without constraints and when one zooms out far enough, one can see some broad similarities in patterns of lexicalization [110].

Within the domain of morphology and syntax, we likewise see substantial differences [61,111]. Information that is required by the grammatical system of one language may seem redundant and overbearing to speakers of another [22]. While some languages, such as Georgian, have rich inflectional and derivational systems of prefixes and suffixes expressing tense, number, aspect, and so on, others, such as Vietnamese, have little to none [112] and languages vary substantially in the depth of syntactic recursion they use [113–115]. Although controversial, it has even been suggested that seemingly fundamental building blocks of language (nouns, verbs, adjectives, and adverbs) are perhaps not universal, as evidenced by languages such as Straits Salish [116].

Phonology (the aspect of language perhaps most obviously constrained by physical limitations on production and perception) shows substantial differences in phoneme inventory size, syllable complexity, and patterns of stress [48]. Signed and whistled [46,117] languages further highlight the diversity to be found in this domain.

It could be that all languages really comprise the very same elements, differently arranged. However, concluding from this fact that differences between languages are marginal is a bit like concluding that, because all animals use the same four DNA bases, differences between them are merely superficial.

Drift versus Adaptation

A standard account of how different languages form is uncannily similar to the traditional folk tales related by the opening quote. Languages change over time. If everyone always spoke to everyone else, these changes might spread evenly to the entire speech community. However, people are more likely to communicate with their neighbors, thereby 'inheriting' their ways of speaking. This asymmetry means that variation within a group will become increasingly decoupled from variation between groups, leading to the eventual formation of dialects and languages [13,14]. An analogous situation arises in biology. Genomes are undergoing constant changes and these changes are more likely to be inherited within a population than between populations. We refer to this divergence due to accumulation of changes as **drift** (see Glossary for a distinction between the biological and traditional linguistic senses of the word).

Is drift all there is? No biologist would suggest that the only reason birds have differently shaped beaks is that the bird populations simply drifted apart. Rather, biologists postulate adaptive processes, with organisms adapting to different environments. Such **adaptation** is self-evident in certain domains of culture. Few would question that differences in what people wear and eat can be understood as adaptations to different environments. Might the same be true for languages?

What Adapts to What?

Unlike biological traits and aspects of culture, such as clothing and diet, there has been deep skepticism about linguistic diversity arising from adaptive processes. For example, some have suggested that, aside from differences in some vocabulary,

> 'we cannot argue for adaptive radiation in any area of language. . .We must seriously consider the possibility that the diversification of language is dysfunctional' [15].

Glossary

Adaptation: in biological evolution, adaptations are changes to an organism that lead to an increase in the frequency of a trait, generally through an increase in the reproductive success of the organism. In cultural evolution, adaptations are changes that improve the transmissibility (and, hence, frequency) of a cultural trait. In the domain of language, such improvements can be achieved by increased fidelity of transmission, greater learnability, more efficient comprehension, and so on.

Categorical denotation: unlike sensorimotor experiences, which are always specific, words and larger expressions can denote categories rather than specific goals or perceptual events. This property may allow language to 'transcend the tyranny of the specific' [84].

Compositionality: the possibility of recombining a smaller set of units (morphemes) into a larger set of expressions (words, utterances) through structured recombination. Along with combinatoriality (the combining of meaningless segments into meaningful morphemes), compositionality and combinatoriality comprise the 'duality of patterning' [85].

Drift: the linguistic notion of drift [14] (directed drift) concerns processes such as phonological shifts and grammaticalization. These processes have predictable direction that is to some extent predictable from principles discovered by variationist linguists [11,13,86]. Such directed drift does not explain linguistic diversity because its directedness implies that languages would converge to a common form. That they do not implies a random component akin to the biological notion of drift (random drift), which refers to changes in a trait caused by random sampling among its variants.

Grammaticalization: a process of language change wherein items change from lexical to grammatical meanings; for example, 'going to' changing from its original meaning of literal motion to having a grammatical function of marking intention and/or the future. In becoming grammaticalized, items often become reduced in form (hence, 'going to' frequently becoming 'gonna') [73].

This skepticism extends to the basic components of speech, sound systems: '[p]honological processes are not adaptive [. . .]. There is no correlation whatever between [. . .] any aspect of linguistic structure and the environment. Studying the structure of a language reveals absolutely nothing about either the people who speak it or the physical environment in which they live' [16]. The structure of particular languages cannot conceivably relate to their environments because, it is believed, 'nothing [m]akes Japanese word order more effective on Pacific islands and English word order better on Atlantic islands. Indeed, there is no ecological regularity in how the major linguistic types are distributed around the world' [17].

There are several reasons why these confident assertions have gone largely unchallenged (*cf*. [18–26]). First, there has been confusion about what it means for one language to be a better fit to an environment than another language. This has traditionally discouraged consideration of fitness, because early discussion often accompanied racist overtones and suggestions that some languages imply superior cultural development (discussed in [13]). Second, detecting signatures of adaptation requires augmenting the case-study (idiographic) approach used in historical linguistics and linguistic anthropology with a large-scale statistical (nomothetic) approach.

A growing number of studies have begun to uncover ways in which languages may adapt to their environments and the mechanisms by which such adaptations may occur. Here, we present evidence from three domains in which aspects of language show signs of adaptation, creating relations between: (i) grammar and social structure; (ii) phonology and ecology; and (iii) linguistic registers and external communication technologies. We then briefly discuss the mechanisms by which these adaptations occur.

Adaptation to the Social Niche

Natural language is strongly constrained by what can be learned by infants [27,28]. An aspect of language that can only be learned by 50% of infants will propagate considerably less well than one that can be learned by all infants. However, not all languages are similarly constrained by what can be effectively learned by adults. Some languages have large populations of non-native (**L2**) speakers. For example the majority (64%) of English-speakers and most of (90%) of Swahili-speakers are L2 speakers. In contrast, most smaller languages (and some larger ones, such as Turkish and Japanese) are learned almost exclusively by children as native languages [29].

Insofar as certain linguistic patterns, such as complex inflectional morphology, are harder for adults to learn and use [30], these patterns should be selected against by L2 speakers [18,31]. In a large-scale test of this hypothesis that used speaking population, geographic spread, and language contact as proxies for L2 populations [21], it was found that languages spoken by more people and in more diverse social environments had considerably simpler morphology (Figure 1). Compared with languages spoken by fewer people, they tended to: (i) rely more on the use of standalone lexical items for communicating meaning, for example encoding distinctions in tense, aspect, and evidentiality using lexical means (e.g., 'It sounds like the meat is charring') rather than more grammatical devices (e.g., from Koasati, *nipó-k aksóhka-ha*: meat-SUBJ, char-AUD EVIDENTIAL); (ii) have simpler systems of case-markings and rely more on word order for communicating who did what to whom; (3) have simpler verb conjugation systems; and (4) have simpler grammatical gender, or no grammatical gender at all. Subsequent work found that some linguistic patterns (such as the marking of case) are specifically correlated with the proportion of L2 speakers [32].

How can an influx of L2 learners change the structure of a language? Consider a child learning English as their native language from parents who are L2 English speakers. That child will go on to become a fluent speaker, but their English may be influenced, however subtly, by their

L1/L2: conventionally, L1 refers to an individual's first and/or native languages and L2 to a language learned later during childhood or adulthood.
Repair: in conversations, repair is a process that interrupts the flow of conversation to clarify miscommunication or misunderstanding that has arisen. Repair often takes the form of explicit revision or elaboration by one or both parties of a conversation [87].
Productivity: the ability of natural language to convey novel information. Together with compositionality, the productive capacity of language allows hearers to understand and produce novel utterances.
Spatial deixis: one of the ways languages convey spatial location is through deictic words, such as 'this', 'that', 'here', and 'there.' The meanings of these words require knowing a considerable amount about the context of the utterance.

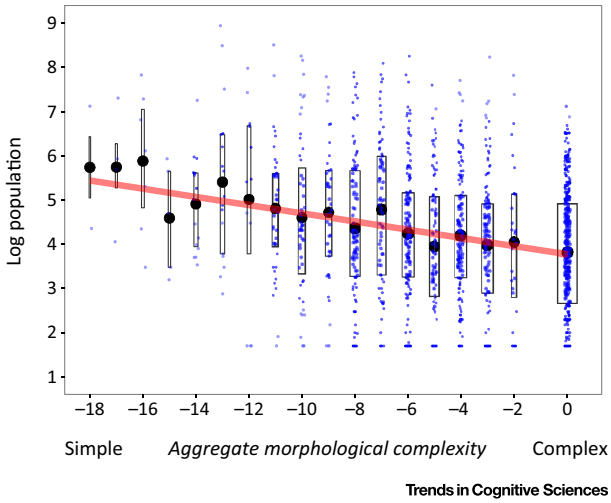


Figure 1. The Relation between Morphological Complexity and Population. Languages spoken by more people tend to have simpler morphology, a result previously argued [21] to support the linguistic niche hypothesis; that is, the structure of languages adapts to the environments in which they are learned and used. The working hypothesis that explains this particular relation (which survives multiple controls) is that languages spoken by more people have larger populations of non-native speakers who impose an additional selective pressure on the language by decreasing the frequency of complex morphology in favor of lexical strategies.

parents' input. The child may then go on to (partly) reproduce that bias when conversing with other L1 speakers, influencing the language statistics they experience, which will influence their own production, and so on (see [18,33] for further discussion and a computational model). There is some skepticism that such influences can change language in a meaningful way, especially when the language is dominated by L1 speakers [34]. Further work is clearly called for [35].

It is unlikely that the relations uncovered by these analyses can be explained solely by the differences in the learning abilities of L1 and L2 speakers. An intriguing alternative explanation is that larger groups expose speakers to a greater diversity of conversational partners, with the effect of enlarging the available space of variants from which morphologically simpler ones may be selected. Although this hypothesis was not supported in a recent study [36], the more general idea that different levels of social and/or linguistic heterogeneity may be an important factor in language diversification is worth investigating.

Another example of learnability-based selection can be glimpsed in the emergence of sign languages in communities with large proportions of deaf individuals. These 'shared sign languages' are learned and used by both deaf and hearing individuals [37]. Just as spoken languages must be learnable by hearing infants, shared sign languages must be learnable by deaf infants. However, unlike more conventional 'urban' sign languages, shared sign languages are additionally selected to be learnable by hearing individuals (to a greater degree than conventional 'urban' sign languages). This additional pressure on shared sign languages has possible consequences for their structure [37].

A variety of cultural factors form additional selective pressures. For example, taboos against using particular names or referring to particular social relations may promote idiosyncratic strategies, such as the use of gestures [38,39]. A focus on social hierarchies may promote (i.e., select for) grammaticalization (and, thus, more obligatory marking) of honorific titles [40]. Viewed through the adaptationist lens, we can think of such changes as instances of language adapting to the demands of culture. A language without grammaticalized honorifics can be thought to be less well adapted for use in a culture that places particular importance on deference.

Adaptation to the Ecological and Physical Niche

Although often studied as abstract systems of rules [41], actual languages are used by real people in real places. How might language adapt to bodies and places? The sound systems of all

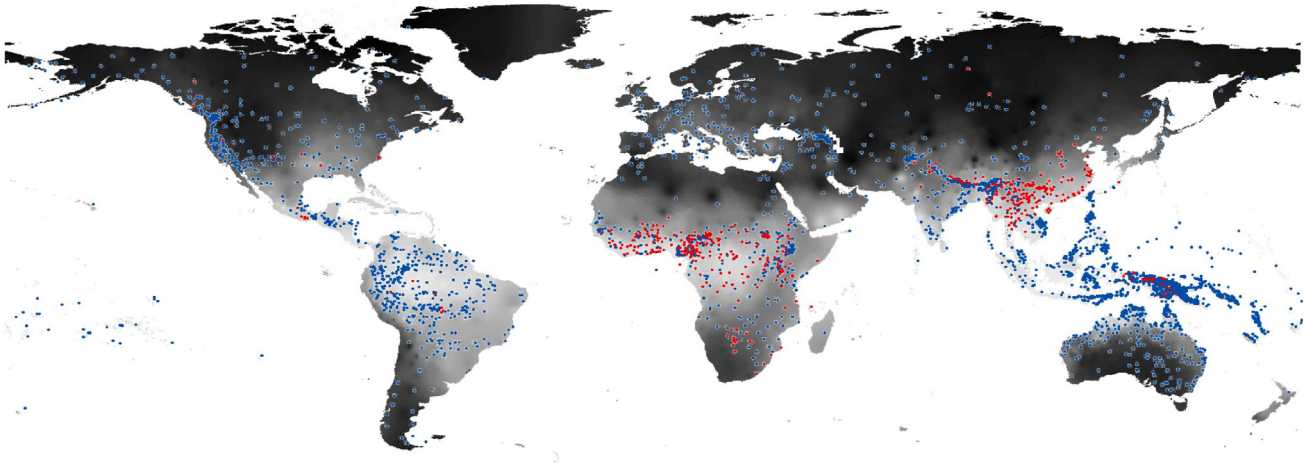
languages are clearly constrained by what people can produce, hear, and discriminate. However, what sounds are best discriminated and propagated can depend on ecological factors, such as climate and vegetation, and on subtle differences in the perception and production capacities of different human populations.

The claim that the sound system of a language may be constrained by the ecology in which the language is used (its ecological niche) may appear radical, but such an acoustic adaptation hypothesis has a long history in the study of nonhuman animal communication systems [42–44]. Perhaps the strongest example of acoustic adaptation in the domain of language is the emergence of whistle forms of language, of which about 30 are documented [45]. These language forms typically transpose vocal speech into a system of whistles. Speakers of Silbo Gomero in the Canary Islands, the most-studied whistle language, have been observed to communicate over distances of 10 km [46]. Although such language forms are variants (registers) of more conventional spoken language, critically for our hypothesis the variants are not randomly distributed (i.e., they do not result from a purposeless accumulation of changes), but tend to be found in places where a strong pressure to communicate over long distances is combined with difficult-to-traverse terrain; this is a clear case of acoustic adaptation, whereby a sound system has adapted to its environment.

Evidence that sound systems of conventional spoken languages show signs of such adaptation is subtler, but persuasive nevertheless. For example, a temperate climate with open vegetation allows for easier transmission of consonants and/or higher frequency sounds than warmer climates with denser vegetation, which better propagate vowels. There is some evidence of a relation between climate and prevalence of vowel use [47,48], although more direct evidence for the specific influence of the environment is needed. A more convincing example is the recently reported relation between temperature and/or humidity and whether a language uses lexical tone (i.e., the use of rising and falling pitch patterns to mark differences between words). Languages spoken in dryer climates are less likely to use lexical tone, possibly because dry air can stymie the precise vocal control required for making tonal distinctions (Figure 2) [49,50]. Alternative mechanisms have been proposed [51], but whatever the mechanism, the observed relation between climate and lexical tone (which survives controls for various confounds) supports on which cross-linguistic differences in sound systems may be partly accounted by adaptation to different environments.

Although the sound systems of all languages are constrained by the sounds that people can perceive and produce, not all groups of people may be equally proficient at producing and perceiving a given set of speech sounds. Such differences, even if vanishingly small, can over time further contribute to linguistic diversity. For example, the use of lexical tone can be partly predicted from two derived haplogroups of genes linked to brain growth and development [52]. An intriguing possibility is that these genes may in some indirect way confer more precise vocal control or finer perception of pitch contours, which have been shown to differ between ethnic groups [53]. Such associations suggest ways in which the diversity of sound systems found in languages may reflect adaptations to slightly different environments.

Beyond phonology, languages spoken in environments with salient topography (mountains or large bodies of water) sometimes grammaticalize these geographic features for **spatial deixis**, while languages spoken in environments more strongly shaped by human artifacts tend to rely on reference to artifacts and speaker-centered coding (e.g., left and right) [54]. It has been suggested that complex deictic expressions common in some languages arose as a way to signal about the location of objects in environments that have relatively few human artifacts [55]. Saying ‘across the street’ or ‘next to the mailbox’ is not an option for a language spoken in an environment that does not have such landmarks and artifacts. The process of



Trends in Cognitive Sciences

Figure 2. The Relation between Climate and Use of Tone. Languages that use lexical tone (red dots) tend to be distributed in warmer and more humid climates (lighter shading) than languages that lack tone (blue dots) [49] possibly due to dryer air making precise vocal control more difficult. Reproduced, with permission, from [49].

grammaticalization of geographic and/or topographic features may be of the same type as well-attested grammaticalization in other aspects of language, such as tense [12]; such grammaticalized forms may be more functional (and, thus, more likely to be selected) in languages spoken in particular geographical environments.

Adaptation to the Technological Niche

So far, we have treated each language as a single system. However, each language has a variety of forms (registers) and speakers 'adapt [their] language to the immediate context of the speech situation' [15]. For example, there are systematic differences between informal speech and formal written language [56]. Such differences are not random, but can be viewed as adaptations to different technological niches. To illustrate, we focus on the ways that language adapted to being written and the way that it is now adapting to modern electronic communication (Box 2).

Spoken language must be processed as it is spoken (i.e., in real-time). This 'now or never bottleneck' [57] acts as a strong selection pressure against words and grammatical constructions that cannot be easily parsed in real-time. In conversation, this process is typically aided by a shared context between speakers and by a variety of extralinguistic and/or pragmatic aids, such as gestures, facial expressions, prosody, and so on. Comprehension failures, when they occur, can often be quickly **repaired**.

For most of human existence, all language benefitted from these aids because language was largely restricted to face-to-face communication. This changed with the invention of writing. Written language must stand on its own. It does not benefit from interactive repair and lacks the rich pragmatic and extralinguistic cues present in face-to-face communication. The durable medium that is the written form relaxes the now-or-never bottleneck, allowing readers to process the text at a more leisurely pace, rereading as necessary. Prosody was partly replaced by punctuation (a surprisingly late development in the history of writing [58]). To avoid ambiguity and increase efficiency, the written register led to an expanded vocabulary and greater syntactic complexity [56,59–61]. This added complexity is not without cost. Written language tends to be harder to process than spoken language, but this added cost is partly offset by the reader's ability to slow down and reread if necessary (Box 2). There is some evidence that learning to read, (i.e., becoming trained in a language register that has evolved to fill the particular needs of the written modality) augments several cognitive and perceptual abilities [62], and affects the

processing of spoken language. Research here is sparse, but there is some evidence that literate speakers have a stronger representation of words as individual recombinable units [19,63,64] and that experience with notation more generally (e.g., musical notation) may aid people's ability to reproduce novel compositional structures [65].

A more recent case of language adapting to the technological niche can be seen in how written language has been responding to the pressures imposed by modern electronic communication. For the first time in history, there is a pressure on written language to convey, in real-time, the nuances of face-to-face conversation. Ironically, the very adaptations that enabled written language to stand on its own make it ill suited to meet the pressures of real-time conversation (Box 2).

This pressure for using written language for real-time communication was quickly met through novel conventions (Internet slang) for expressing pragmatic and emotional information including emoticons: *:)*, acronyms: LOL, and novel uses of typographic marks such as ellipses: . . . [66]. Skilled writers may be able to convey all the information conveyed by these novel forms through conventional text alone, but unlikely to do so in real-time. The result is what John McWhorter has called 'fingered speech.'[i] These conventions (some of which are several decades old) are now rapidly losing ground to emoji, the use of which shows a strong correlation with the ability to produce them using easily accessible keyboards; this is a clear example of how easing a production constraint affects production frequency (Box 2 Figure ID,E).

The divergence between written and spoken language and between conventional written language and Internet-enabled real-time written communication is, in many respects, different from the divergence between conventional spoken languages, such as the divergence between Dutch and Afrikaans. What both of these processes have in common is that they show ways in which languages (or language registers) adapt to the environments in which they are used. Just as we can hypothesize about the influence that learning biases of L2 learners played in the divergence between Afrikaans and Dutch [67], we can hypothesize about the ways in which the written form of language diverges from the spoken form as an adaptation to this new environment.

Box 2. From Written Language to Emoji: How Language Adapts to New Technologies

It is useful to view the impact of technology on language through an adaptationist lens.

Figure IA shows the kind of language that can be generated when the now-or-never bottleneck through which all spoken language must pass is relaxed. The opening sentence of *The Crying of Lot 49* contains syntactic complexity far exceeding that of spoken English, requiring slower and more deliberate processing for which spoken language is ill suited. The sentence from *The Things They Carried* is easy enough to comprehend in real-time, but sentences of such elegance and narrative power certainly cannot be created in real-time.

The use of the written modality for real-time communication has created a new set of pressures on written language (e.g., Figure IB), which have been met by a variety of 'internet slang', such as LOL (laughing out loud), JK (just kidding),:) (smiley face), that help to fill in for the missing pragmatic and prosodic information. Some slang, such as LOL is derived from longer linguistic expressions, but it is not a literal replacement for the phrase, rather, it is depictive, a partial replacement for an actual laugh (at least in its original meaning). Much of this slang is now being supplanted by emoji. Figure IC shows the 16 most frequent emoji on Twitter with the number of tweets containing the respective emoji (as parsed by Emojitracker.com between July 4, 2013 and May 25, 2016). Figure ID shows the rapid increase in the use of emoji on Instagram. Almost 40% of Instagram posts now contain at least one emoji. The trend shown is suggestive of the impact that reducing the production cost of emoji by introducing emoji keyboards has had on their popularity.

Figure IE shows four cohorts of Instagram users. All cohorts show an increase in emoji use and a corresponding decrease in the use of text-based slang, suggesting that emoji are replacing the functions served by text-based slang.

A Yik-Yak post (a Yak) published on the campus of University of Wisconsin-Madison in May, 2015 (Figure IF), shows one way in which emoji do not simply replace words but create novel opportunities for self-expression through a type of depiction [118] that is not possible by conventional written language.

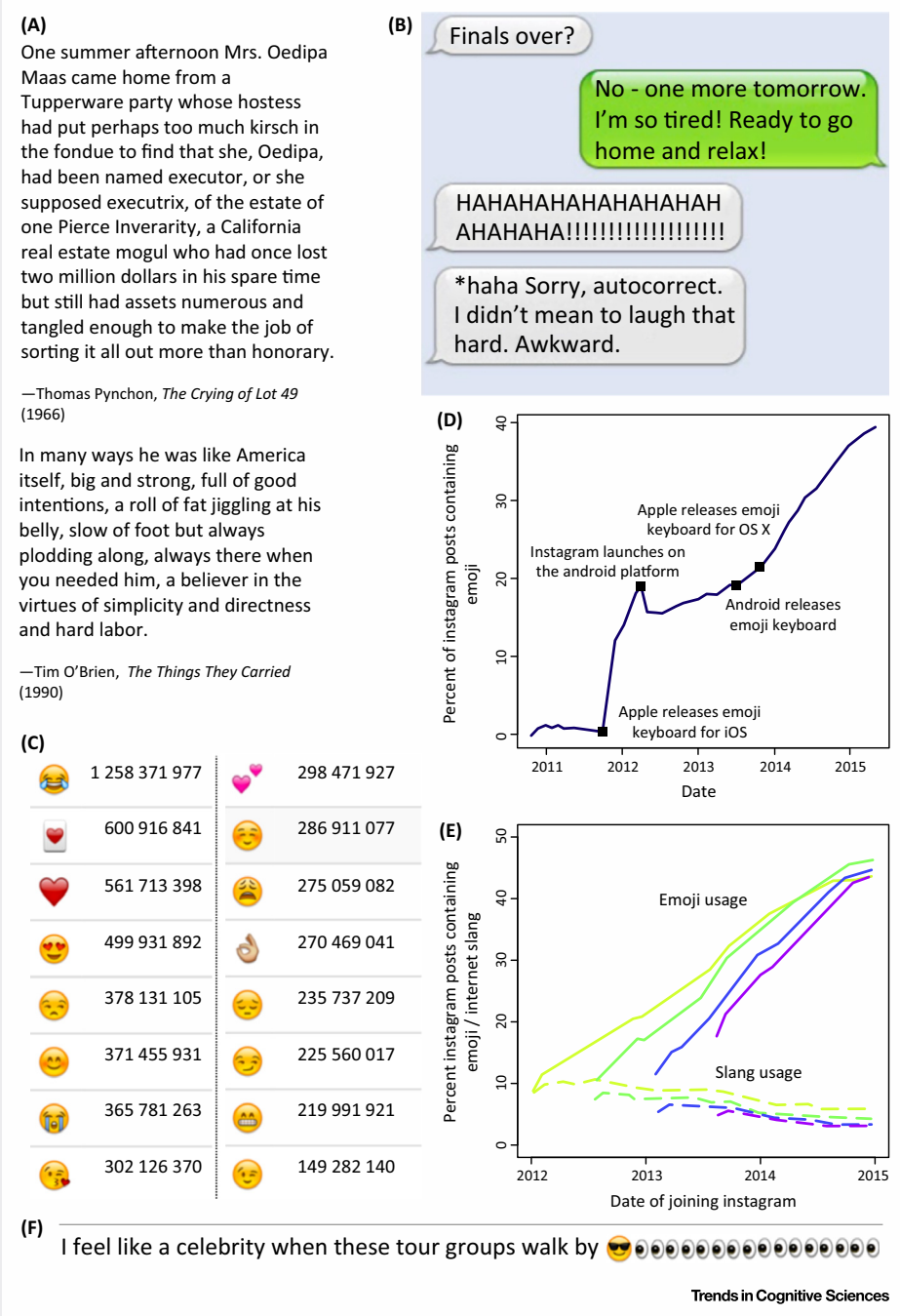


Figure I. Writing and Electronic Communication under an Adaptationist Lens. (D,E) adapted from an analysis of Instagram posts by Thomas Dimson[ii].

What Are the Mechanisms by which Languages Adapt?

How does language adapt to its environment? While many details remain to be worked out (see Outstanding Questions), we believe the basic mechanism is straightforward, sharing much with the functionalist tradition in linguistics [68]. In learning and using a language, people traverse a

high-dimensional space of possibilities. Does one say 'Whom should I talk to?' or 'Who should I talk to?', 'Impossible' or 'Not possible'? Many factors will predict the choices that speakers make. These include the full range of factors studied by sociolinguists, such as prescriptive norms, and the full range of general cognitive factors that will render some variations more accessible, easier to produce, predict, and understand [69–71]. In combination, these factors create a fitness landscape in which forms with greater fitness are more likely to survive.

Critically, the fitness landscape is different for different environments. The landscape generated by an L1 speaker is different from that of an L2 speaker. Small differences in fitness of an utterance translate to different frequencies of produced forms, compounding over time to the kinds of more substantial difference that characterize different languages [72]. Similar to usage-based theories of language [73], the proposed mechanism for language adaptation focuses on the role of individual speakers who create innovations that spread or fail to spread through a speech community. The same logic applies to selection between phonological and/or phonemic variants and to the influences of technology. For example, the way that the emergence of written language can lead to an expanded vocabulary or more complex syntax is via positive selection of such variants. Insofar as being able to read allows people to more easily produce and understand certain utterances, such utterances will be more likely to propagate.

So Why Are There Different Languages?

The evidence above begins to paint a picture of languages diverging not simply due to gradual accumulation of random changes, but also in response to different pressures from the contexts and mechanisms of language use. Is a language spoken only by native speakers in several villages, or by hundreds of millions, including many L2 speakers? Do speakers of a language have vocal tracts that subtly facilitate production of certain sounds? Is the language spoken across varied topologies or in an environment with salient geographic features? Does the language have a written form? These are just some of the pressures to which different languages may adapt and, in so doing, diversify.

As is true for biological differences, not every linguistic difference is an adaptation. Many, perhaps most linguistic differences, may reflect historical happenstance having no functional consequences. Other factors, such as marking group identity, are also likely at work, further magnifying linguistic diversification [74,75]. However, the existence of these processes does not mean that languages do not also adapt to their environments, much as the function of genetic drift in creating biological diversity does not rule out adaptive processes, such as natural selection.

Concluding Remarks and Future Perspectives

Languages differ. Even if one could identify universal building blocks from which all languages are constructed, the differences between languages are neither marginal nor superficial, much as the differences between animals are very much real despite a reliance on a common genetic code. Are the differences between languages merely the result of the accumulation of many small changes (random drift)? The evidence we review here suggests that they are not. Knowing the social, ecological, and technological environment of a language allows us to make informed predictions about its sound system, lexicon, and grammar, all signs of languages not merely changing under their own internal constraints or being at different points on a common grammaticalization cline [12], but adapting to the environments in which they are learned and used.

In pursuing the new frontier of the linguistic adaptation, we must proceed with caution. We need to be careful when using correlational analyses to make claims about adaptation and in over-ascribing adaptive value to all linguistic differences [76,77] (see Outstanding Questions). One way to help test causal links is through simulations, communication games, and studies involving

Outstanding Questions

What can we do to strengthen our causal inferences about language–environment associations in the absence of the ability to perform true experiments?

Can we develop better ways of distinguishing among (i) language changes that are truly random; (ii) changes caused by language-internal processes; and (iii) changes caused by environmental selection?

Can we integrate the richly detailed literature in variational linguistics that tends to focus on one or several languages, with large-scale but necessarily much coarser statistical analyses that involve hundreds or thousands of languages?

Can we better integrate theories of human learning and language processing with quantitative models of cultural evolution to better understand the dynamics of language change?

Can we build better models of the ways that small changes to culturally transmitted systems on a short timescale compound to produce larger changes on longer timescales?

Can we directly observe how placing a language in a new environment (e.g., through mass migration or colonization) causes rapid change as it adapts to that new environment?

Does genetic variation between human groups contribute to observed linguistic differences (particularly at the level of language families)? If so, how strong is this influence?

To what extent has literacy influenced spoken language? Can lessons from writing help us understand how present and future technologies can influence spoken language?

How is modern information and mobile technology shaping language in the present, and what can we expect from future generations of language users who are influenced by this technology?

artificial languages [7,35,36,78–81] that enable experimental tests of hypothesized mechanisms on a smaller scale, but in a more controlled environment. An added benefit of this approach is bridging the rich literature of variationist linguistics (e.g., [34,82,83]) with experimental cognitive science [35,70,79].

Despite the challenges, we believe that viewing languages as adaptations to different environments will help advance our understanding of linguistic diversity, language origins, and the ways in which cultural evolution contributes to shaping the human mind.

Acknowledgment

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Resources

[i] www.ted.com/talks/john_mcwhorter_txtng_is_killing_language_jk

[ii] http://instagram-engineering.tumblr.com/post/117889701472/emojineering-part-1-machine-learning-for-emoji

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