Empirical foundations for an integrated study of language evolution

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Abstract

Half a century ago, Uriel Weinreich, William Labov, and Marvin Herzog laid out a programmatic vision for the study of language change. This included establishing five fundamental problems for the field and a radical shift from a focus on idiolects to a focus on population-level change (grounded in their concept of orderly heterogeneity). They also expressed an explicit desire to see an integrated evolutionary study of language change. In spite of this, the newer fields of language evolution and cultural evolution make little contact with the field of sociolinguistics that emerged out of their work. Here we lay out a program, grounded in their five problems, for a more integrated future. We situate each problem in modern sociolinguistics and identify promising points for theoretical exchange, making comparisons with Tinbergen's four questions, which play a similar role in the evolutionary sciences. Finally, we propose cultural-evolutionary experiments for making empirical progress.

Keywords: Sociolinguistics, language evolution, language change, cultural evolution, experiments

1   Introduction

In 1968, Weinreich, Labov, and Herzog (1968) (henceforth WLH) published a paper, *Empirical foundations for a theory of language change*, that well justifies the term "seminal". In it they took stock of the legacy of work on language change up to that point, laid bare persistent problematic assumptions in that work, made the case for population-level thinking, and set out five fundamental problems for the study of language change. They also expressed an optimistic vision of a united science of language evolution encompassing the biological and cultural evolution of language, with sociolinguistics an integral part. In this paper, by reviewing each of WLH's main contributions in the context of recent work on language evolution, we outline a research program for realizing their broader vision.

The contribution for which WLH's paper is best remembered is its establishment of five problems for the field. They are as follows.

The Actuation Problem. Why does a change in a particular feature take place in a particular language at a particular time, but not in other languages with the same feature, or in the same language at some other time?

The Transition Problem. How does a language move from one state to another, and how are changes transmitted between speakers?

The Embedding Problem. How is change embedded in linguistic structure and social structure?

The Evaluation Problem. What role does social awareness play?

The Constraints Problem. What changes are possible, and what factors constrain their likelihood?

We will discuss each problem in more detail in Section 2. In Section 1.2, we will discuss WLH's vision for an integrated evolutionary field of linguistics, alongside the reality of what emerged in the half century following their paper. However, neither their vision for the field nor their five problems can properly be understood without understanding the importance of population-level thinking, which we discuss in Section 1.1.

1.1   Population-level thinking

Generative linguistics in 1968 focused on an "ideal speaker-listener in a completely homogeneous speech community" (Chomsky, 1965, p. 3) as the primary source for data, working under the assumption that an idiolect is "the most consistent and coherent system" (Labov, 1966b, p. 6). Any variable production not attributable to allophonic or morphological rules was considered to be external to language, labelled *free variation* and set aside. WLH pulled the rug out from under this position, presenting a radical upset to what they called the "isolation of the idiolect" (p. 104) and setting forth an argument for the community dialect as the appropriate unit of study. This shift was partly ideological. WLH took the perspective that a change in an individual is *not* change in the language; since language change is a change in the community grammar, the unit of study must be the community. This rationale

is reinforced by the enormous explanatory power that community-level analysis gives to the puzzling individual variability that had previously been set aside. Central to this breakthrough was the discovery of *orderly heterogeneity*: Individual-level variation is replicated on the community level in a structured way and becomes systematically understandable.
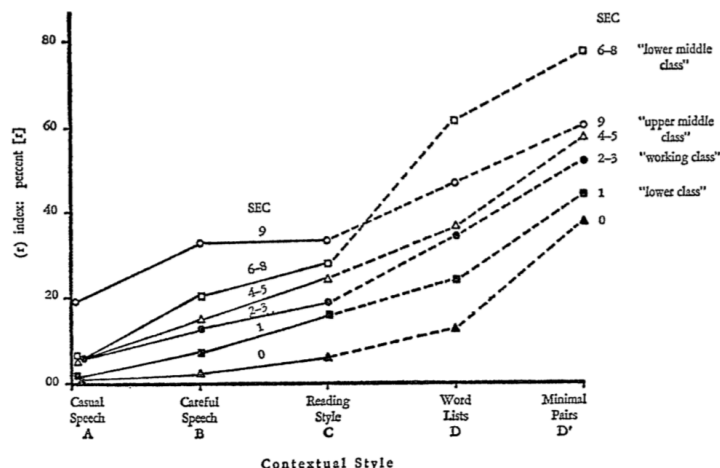

Figure 1: Class and style stratification of /r/ in New York City. Solid lines indicate styles within the conversation portion of the interview; dashed lines indicate the formal methods portion of the interview. From WLH (p. 180)

The explanatory value of orderly heterogeneity has been found in many subsequent studies on language change for both social factors and language-internal factors; the picture that emerges time and again is of the community grammar as more regular than the individual (Ashby, 2001, p. 13). This principle appeared with striking clarity in Labov's work on coda /r/ pronunciation in New York City, illustrated in Figure 1. This displays the rate of coda /r/ produced by speakers along the y-axis, with speaking style along the x-axis in order of increasing formality. Each line represents a different socioeconomic class, ranging from lower class to upper-middle class. The ordering of these lines shows that /r/ pronunciation rates systematically increase with social class. Simultaneously, Figure 1 shows that *within* each social class, rates of /r/ pronunciation also increase as speaking style becomes more formal. This clearly demonstrates the systematicity of community grammar: while individuals are variable, this variation is ordered along the social factors of class and formality. This orderly heterogeneity enables linguists to analyze variation as the result of conditioned probabilistic factors synchronically and as an important driver of language change diachronically.

This new focus on community-level analysis ushered in a new branch of linguistics, characterized by population-level thinking, echoing the paradigm shift introduced to biology by Darwin about a century previously. Population-level thinking also plays a principal role in the field of cultural evolution, as has been emphasized in a number of places (e.g., Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981; Henrich & McElreath, 2003; Richerson & Boyd, 2005). Population-level thinking thus lies not only at the heart of WLH's model of language change and each of their five fundamental problems, but also at the heart of

evolutionary approaches to language and culture more generally. In Section 1.2 we discuss the relationship between language evolution and mainstream sociolinguistics.

1.2   Sociolinguistics and evolution

It is no exaggeration to say that WLH's paper, along with other work by the same authors, played a central role in bringing the field of sociolinguistics into existence. But WLH explicitly positioned their own interests within a broader endeavor that goes well beyond modern sociolinguistics (p. 103):

> We think of a theory of language change as part of a larger theoretical inquiry into linguistic evolution as a whole. A theory of linguistic evolution would have to show how forms of communication characteristic of other biological genera evolved (with whatever mutations) into a proto-language distinctively human, and then into languages with the structures and complexity of the speech forms we observe today. It would have to indicate how present-day languages evolved from the earliest attested (or inferred) forms for which we have evidence; and finally it would determine if the present course of linguistic evolution is following the same direction, and is governed by the same factors, as those which have operated in the past.

This ambitious future envisaged by WLH has not yet come to pass. Modern sociolinguists do not on the whole see themselves as engaging in part of a larger inquiry into language evolution. WLH's recognition that biological and cultural evolution might both be part of the same broad story, perhaps even that calling both "evolution" is more than simply a linguistic convention, is now mostly absent from the field (and most of linguistics). What happened instead is that – in parallel to sociolinguistics, rather than in conversation with it – distinct fields emerged in the decades following this paper.[1] Towards the end of the twentieth century, a distinct field of language evolution coalesced out of rather disparate strands of work from across linguistics, biology, zoology, psychology, anthropology, and other cognitive sciences. The broad goal of that field is precisely to understand "how forms of communication characteristic of other biological genera evolved ... into a proto-language distinctively human, and then into languages with the structures and complexity of the speech forms we observe today", and there is broad appreciation of the need to pay attention to both biological and cultural evolution. The field of language evolution, in other words, looks something like WLH's vision of the future, and researchers within it are paying increasing attention to questions and phenomena that sociolinguists care about. Yet there are very few sociolinguists involved in it, and communication between the two fields is sparse. The same goes for the also recently coalesced field of cultural evolution, devoted to understanding the evolution of cultural behavior broadly speaking. There is significant interaction between that field and the field of language evolution, as evidenced by Youngblood and Lahti's (2018) bibliometric analysis, but very little with sociolinguistics.

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[1]There are of course other relevant fields we do not discuss. Sociolinguistics, for instance, exists in parallel to the field of historical linguistics. (On the relationship between the two fields see Joseph 2011; Lehmann 1981.) Language evolution, similarly, overlaps somewhat with the field of biolinguistics. There is not space in this paper for a discussion of these relationships.

At this point it should be stressed that the existence of parallel fields is not in itself a problem. From an evolutionary perspective, a diverse and heterogeneous pool is in fact rather a good thing, as it should encourage innovation and aid survival (cf. Lehmann, 1981; Roberts, 2017). The benefits of diversity, however, can only be realized if there is communication and innovations are shared. There are in fact a number of innovations to share, both theoretical and empirical, and we do not have space in this paper to cover them all and do them justice. Instead we will make selective connections that we consider illustrative of what we have in mind, while focusing particular attention on one innovation from the field of language evolution in which we have the most expertise, and which we consider to be especially promising for breaking new ground in addressing sociolinguistic questions: experiments involving "laboratory languages" (Galantucci, Garrod, & Roberts, 2012; Roberts, 2017). These experiments can be broken down into distinct types, each with its own particular strengths. In aggregate, and in concert with data from natural language, they can also help tease apart fundamental questions about domain-specificity in the language faculty (Hauser, Chomsky, and Fitch 2002; Keil 1990; Fitch 2010, pp. 20–24). The first type of laboratory language experiment is one in which participants develop a novel communication system (typically in a non-linguistic medium) over the course of the experiment (e.g., Galantucci, 2005; Verhoef, 2012); this is particularly useful for shedding light on questions about the domain-specificity of linguistic properties (e.g., Stevens & Roberts, 2019). A second type of experiment, which Roberts (2017) termed "social group games", has small groups of participants communicating in an artificial language to accomplish a non-linguistic task (Roberts, 2010; Sneller & Roberts, 2018); this type of experiment enables researchers to embed participants in a more engaging social world than is typical for laboratory experiments and allows them to include and manipulate a wide range of social factors; the non-linguistic task also contributes to ecological validity and can help mitigate demand characteristics. The third type of experiment involves participants learning and producing output in artificial languages, where learning the language constitutes the experimental task. Such experiments have a relatively long history in the fields of psychology and language acquisition (Reber, 1967; Saffran, Aslin, & Newport, 2011) and can be used to explicitly test the learnability of certain linguistic properties as well as the role of participant age in acquisition and change (Hudson Kam & Newport, 2005, 2009; Schuler, Yang, & Newport, 2016). Iterated-learning studies form a subset of such experiments, in which the output of one "generation" of participants becomes the input for the next. Experiments of this kind, which have a surprisingly long history (Bartlett, 1932; Esper, 1966), can help reveal patterns of change that might not be apparent in single generations (e.g., Kirby, Cornish, and Smith 2008; Roberts and Fedzechkina 2018; for a review see Kirby, Griffiths, and Smith 2014).[2] Some iterated learning experiments include communication within generations (Kirby, Tamariz, Cornish, & Smith, 2015).

The potential for laboratory-language experiments to inform sociolinguistic questions about language change are clear. However, they are often conducted with rather little attention to the insights of that field. Indeed, Roberts (2017) made the case both for greater communication between the fields of language evolution and sociolinguistics and for the

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[2]An alternative approach is to conduct a number of single-generation trials in which the input data are sampled widely from the space of possible outputs; this can be less costly to run than an iterated-learning experiment but requires that the space be reasonably well defined from the outset.

wider use of laboratory-language experiments to answer questions from the latter. But no one to our knowledge has outlined a programmatic approach to this enterprise. What, in other words are the difficulties and opportunities involved in greater theoretical exchange between these disciplines? How could laboratory-language experiments contribute to solving WLH's five problems? What would such experiments look like and what questions should they concentrate on?

Our goal in this paper is to sketch some answers to these programmatic questions. We do not consider this to have value only for sociolinguistics. All five of WLH's problems are *mutatis mutandis* crucial for the study of cultural evolution in any domain. Given that they were asked in the context of language, they are also very much native to the cultural domain, and can be fruitfully compared with a different division of empirical evolutionary space, Tinbergen's four questions (Tinbergen, 1963), which are laid out in Table 1. These constitute an attempt to map out in a somewhat systematic manner what questions we must ask to attain a full and integrated understanding of behavior in an evolutionary context, incorporating both diachronic and synchronic dimensions on the one hand and proximate and ultimate explanations on the other. While there are clear similarities in intent, there are important differences between the two sets of questions. Tinbergen was very aware of cultural evolution, and these questions have been fruitfully applied to it (Bateson & Laland, 2013; Delius, 1991), but they are nonetheless liable to seem more native to the biological than the cultural domain. They are also organized rather differently from WLH's five problems. While it is possible to impose organization on the latter – such as grouping actuation and transition together as concerned with the beginning and subsequent trajectory of change, grouping embedding with evaluation as concerned with the environment in which a change occurs, and treating the constraints problem as marking the boundaries of both concerns – it is fair to say that they map the space of possible questions much less systematically than Tinbergen's questions. But both sets of questions do share a commitment to population-level thinking. All of them were asked in the light of it, with some (such as WLH's transition problem or Tinbergen's ultimate-explanation questions) making sense only in that light.

Table 1: Tinbergen's four questions, organized following Nesse (2013), though with slight adjustments of terminology.

		Object of explanation	
		Diachronic	Synchronic
Type of explanation	Proximate	Ontogeny *How does the trait develop in an individual?*	Mechanism *What is the structure of the trait, and how does it work?*
	Ultimate	Phylogeny *What is the phylogenetic history of the trait?*	Adaptive function *How does variation in this trait affect fitness?*

In the remainder of this paper, we examine each of WLH's problems in turn, making

comparisons with Tinbergen's questions. (See Figure 3 for an attempt to map the former onto the latter.) For each problem, we lay out how it is best understood in the light of modern linguistic research; we then discuss opportunities for theoretical exchange with explicitly evolutionary fields, and suggest ways in which laboratory-language experiments can be used in the future to shine a light on these problems.

2 The five fundamental problems

2.1 The actuation problem

The actuation problem has attracted perhaps the most attention as a difficult problem (Milroy, 1992) and is the only one of the five problems to frequently be referred to by name in later literature. The puzzle is this: Why does a given change happen at a particular time in a particular variety of a particular language, and *not* at another time, in another variety or language where the same conditions seem to apply? In linguistic approaches centered on the individual rather than the population, the actuation problem seems to be about why particular speakers make particular innovations. Given that linguistic innovations have to start somewhere, this question remains relevant even in more population-oriented approaches. However, population-level thinking introduces an extra element to actuation: propagation. The importance of this element was highlighted by Labov, Yager, and Steiner (1972, p. 7), who went so far as to say that unless the innovation is *also* taken up by the rest of the community, it cannot be considered an actuation:

> The general position that we have taken is that no useful distinction can be made between a change and its propagation (Weinreich et al., 1968) [...] The language does not change if one man invents an odd form or develops an idiosyncrasy, even if people understand and evaluate his behavior; it does change when others adopt his idiosyncrasy and use it as a new social convention for communicating their intent.

There are thus two parts to the actuation problem. The first is concerned with the emergence of innovation on an individual level and the second is concerned with how innovations spread between speakers. Attempts to identify patient(s) zero in a given change are unlikely to yield much fruit and, in general, data on the innovation of change in individuals are hard to obtain. This does not mean, however, that there has not been substantial theoretical work on this problem. Many have pointed to child language acquisition (e.g., Cournane, 2017; Lightfoot, 1979, 2006; Paul, 1880) as the most likely site for actuation. The idea is that a child acquiring language must posit a grammar to account for input, which may differ from the grammar that produced that input (e.g., Andersen, 1973). Here, precise theories of acquisition are essential, as they can produce specific predictions about *when* and *how* children are likely to posit a new grammar from a given set of input. Sneller, Fruehwald, and Yang (2019), for instance, used a computational simulation based on Yang's (2016) Tolerance Principle of acquisition to predict the precise point of dialect mixture in the input that will result in children reanalyzing the grammar. The connection between errors in acquisition

and language change[3] was highlighted by Kroch (2000), who argued that failures of transmission resulting in language change "seem to occur in the course of language acquisition; that is, they are failures of learning" (p. 700). There is, in fact, substantial evidence from child language data that children often produce constructions not present in their input, but this does not fully resolve the innovation component of the actuation problem: We still want to know *why* children introduce the changes they do. Structuralists (e.g., Martinet, 1955) have pointed to the inherent tension between an asymmetrical vocal tract and a desire for a symmetrical inventory as a primary source for phonological innovation. Covert variation has also been pointed to as a possible source of change. For instance, Han, Musolino, and Lidz (2016) found substantial variability across Korean speakers in how they analyzed syntactic verb position, and Baker, Archangeli, and Mielke (2011) similarly found wide variability across American English speakers in which phonological contexts used a bunched or retroflexed coda /r/ articulation; these both provide examples of a lack of evidence in the input resulting in different individual grammars across speakers.

The idea that errors in child language acquisition are the primary source for linguistic innovation is not without controversy, however (see, e.g., Diessel, 2012). Bybee and Slobin (1982) found that nearly all recorded misparsings in child language are repaired before adulthood, arguing that these are therefore an unlikely source for language change. The high rate of repair is not in fact incompatible with child language acquisition being the primary source of language change; it suggests, however, that if children are the main source of change, then change should be rare. We may further ask: Which misparsings are *less* likely to be repaired before adulthood? Are there social or linguistic constraints on repair? Furthermore, whether or not child language acquisition is the *primary* source for language change, it is certainly the case that adult-to-adult language contact has also been a source of change (e.g., Cheshire, Adger, & Fox, 2013; Herold, 2009; Thomason & Kaufman, 1991). This can result from accommodation, simplification of features in dialect contact, or L2 acquisition mistakes (Bentz & Winter, 2013). Research showing that children and adults learn language differently (Newport, 2019) adds another dimension, suggesting that certain types of changes may be more likely to be innovated by adults and others by children.

Finally, successful actuation also requires that an innovation propagate beyond the innovator; in this vein, Milroy and Milroy (1985) laid out a tripartite classification of innovation success. Level 1 innovations do not successfully propagate; level 2 innovations diffuse into a community that the speaker has contact with, via direct interactions; level 3 innovations subsequently diffuse into other communities that the innovating speaker does *not* have direct contact with. For any change to be successful on a population level, it must reach level 3. The actuation of such a change, however, can reasonably be considered to correspond to the first two levels. That is, the propagation aspect of the actuation problem considers how an innovation extends into the linguistic repertoire of the innovator's interlocutors. Childhood peer-to-peer propagation is often appealed to here, particularly for school-age children (Labov, 2001, p. 449). Nardy, Chevrot, and Barbu (2014) provided evidence of peer-to-peer convergence overriding patterns of variation acquired by children before entering school. We will set aside the broader question of how a change, once started, will propagate through

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[3]While child-originated changes are often called acquisition "errors", we follow Kroch (2000) in asserting that these may also be characterized as effects of perturbations in input.

the community (see Section 2.2 for the transition problem); for the actuation problem, we restrict propagation to the smaller question of a level 2 innovation.

2.1.1 Opportunities for theoretical exchange

In terms of Tinbergen's four questions, the actuation problem is (as a diachronic *why* question) best thought of as part of the Phylogeny question; it is concerned, that is, with how a trait's phylogenetic history gets started, to which Tinbergen's Ontogeny question is clearly also relevant, though it is worth noting that the precise details of what ontogeny means in the cultural domain are rather less clear than in the biological domain. The focus of the actuation problem on why a particular trait got started in one place and not another apparently suitable place is also familiar outside linguistics. To take a biological example: Of the four groups of corbiculate bees, only three have evolved eusociality. The question of why the fourth group is not eusocial in spite of appearing in similar habitats has been a stimulus to research (Cardinal & Danforth, 2011). However, despite these broad similarities, there are important differences in the emphases and assumptions that researchers from different fields bring to the questions of innovation, propagation, and child versus adult learning. In what follows, key points of difference for each, along with suggestions for fruitful theoretical exchange, will be discussed in turn.

Innovation in the field of cultural evolution is widely divided into random "cultural mutation" and nonrandom "guided variation"[4] (Richerson & Boyd, 2005, p. 69). The former includes such things as random errors in social learning or changes due to misremembering information. The latter includes more goal-driven innovations by individuals, such as the invention of new traits or adaptive modifications to existing ones.[5] Little time has been spent on an equivalent distinction in sociolinguistics, partly due to the dearth of data on the propagation component of actuation and partly due to the lack of a fully articulated theory of innovation or learning that could could clearly disambiguate between random and nonrandom innovation. It is also not the case that a fully articulated theory of innovation exists in cultural evolution or language evolution, and distinguishing random from nonrandom innovation is not a trivial problem for many cultural domains (language included). The establishment of an integrated theory of innovation would be a valuable objective.

Two points should be discussed concerning propagation in cultural evolution. The first concerns drift and selection and the second concerns debates as to the nature of cultural transmission. The basic evolutionary distinction between drift and selection has been applied profitably to sociolinguistic questions (e.g., Newberry, Ahern, Clark, & Plotkin, 2017) and will be discussed further in Section 2.2.1. With respect to selection in particular, however, Richerson and Boyd (2005) provided a useful tripartite distinction between content-based bias (driven by the nature of the variant being transmitted), frequency-based bias (driven

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[4]This use of "guided variation" to mean non-random innovation should not be confused with the way *variation* is used in sociolinguistics.

[5]A related distinction is between individual and social learning (Feldman, Aoki, & Kumm, 1996; Rendell et al., 2010), where the former refers to the acquisition of traits through engagement with the environment and the latter refers to acquisition of traits by observing others. Individual learning is a subcategory of guided variation, while social learning corresponds roughly to propagation, and is a context in which both random mutation and guided variation occur.

by its perceived commonness or rarity), and model-based bias (driven by perceived characteristics of its users). On the one hand, this distinction is obviously relevant and useful to sociolinguistics; on the other hand, work in sociolinguistics can offer valuable theoretical refinements of these categories. For example, Silverstein's (2003) and Eckert's (2008) work on *orders of indexicality* provided theoretical tools for distinguishing different kinds of user characteristic, with consequences for the rate of propagation (see Sneller & Roberts, 2018, for a test of these predictions; see also the discussion in Section 2.4). The second point to be discussed is the debate on the extent to which cultural replication is high-fidelity (like genetic transmission in biology) or whether it is an inherently biased and transformational process (see, e.g., Acerbi & Mesoudi, 2015; Tamariz, 2019). This debate is little known in sociolinguistics,where much work assumes relatively high-fidelity transmission as a baseline (Labov, 2001, p. 449). Greater involvement of linguists on this question would be valuable, however. Questions about fidelity of transmission are not irrelevant to language change, and insights from sociolinguistics, where the process of language transmission has been studied in detail for many decades, may shed useful empirical light.

Cultural transmission, regardless of the nature of the process, is often divided into *horizontal* (i.e., within-generation) and *vertical* (i.e., between-generation) transmission. This echoes the sociolinguistic question of what role children and adults play in language change and has received significant attention in the field of language evolution. All the same, one should be cautious. As the terms are distinguished in the field of language evolution, the distinction is strictly speaking between unidirectional transmission and communicative interaction; while this maps on to some extent to intergenerational vertical transmission and horizontal transmission, the two are importantly not identical. The focus of debate in language evolution is also somewhat different, being concerned primarily with the role of the two factors in explaining the emergence of novel structure (operationalized in terms of "compressibility"). Some researchers have claimed, in particular, that learning plays a key role in this but that horizontal interaction does not (e.g., Kirby et al., 2015; Tamariz & Kirby, 2016). Others disagree (e.g., Fay, Garrod, Roberts, and Swoboda 2010; Galantucci and Garrod 2011; Garrod, Fay, Rogers, Walker, and Swoboda 2010), though both sides agree that horizontal interaction has a crucial role to play in establishing or maintaining "expressivity", or functional referential expressions. To some extent this debate is relevant to the actuation problem in sociolinguistics, in the sense that it follows from the position of those who privilege vertical transmission in the emergence of structure that vertical transmission should play a dominant role in the actuation of structural change. Nonetheless, differences between children and adults with respect to learning have received less attention in the experimental language-evolution literature (though this is changing; see, e.g., Kempe, Gauvrit, and Forsyth 2015; Raviv and Arnon 2018), even though such differences have been invoked as an explanation for typological variation in other language-evolution work (Dale & Lupyan, 2012). There is also increasingly sophisticated work in the broader field of cultural evolution devoted to age structure and social transmission (e.g., Fogarty, Creanza, & Feldman, 2013, 2019; Mullon & Lehmann, 2017), and all fields involved would benefit from greater engagement with this.

It seems clear that a vital goal for the future is to better integrate insights and theoretical distinctions from sociolinguistics, language evolution, and cultural evolution. This is not only a problem to be solved but also an opportunity for fruitful exchange. The comparative lack

of attention in experimental language evolution to child/adult differences has often been criticized, for instance, but there is an opportunity here to use experiments to separate out the roles of vertical and horizontal transmission from the roles of children and adults in change.

2.1.2 Opportunities for experimental engagement

A crucial difficulty holding back progress on the actuation problem in language is a lack of data or, rather, a difficulty in obtaining the kind of data that would shed the clearest light. With natural-language data we are able to obtain snapshots of language as it is being used in a community, but we cannot easily identify innovative variants to observe and plot their propagation, unless we are particularly lucky with the data we happen to have. In cases where we happen to become aware of a change in progress, speakers in crucially transitioning generations can be targeted for research attention (as by Sneller 2018; see also Labov 2018), but this cannot be relied on. While classical phonetic and psycholinguistic experiments can elucidate articulatory and processing biases that may initiate or inhibit innovation, they too can only offer snapshots.

Social group game experiments, like those employed by Roberts (2010) and Sneller and Roberts (2018), however, do offer a real possibility of making new progress on the actuation problem. In these experiments, participants learn a miniature artificial language and use it to communicate with each other while performing a non-linguistic social task. Roberts (2010), for instance, had participants negotiate to exchange resources while attempting to maximize in-group exchanges and minimize out-group exchanges. He was then able to observe the emergence of new "dialects" in the language. There are several reasons why such experiments might be useful. The most fundamental point is that the experimenter can control the initial state of the language and record every instance of it being used. This allows "patient zero" to be identified in a way that is all but impossible outside the laboratory. That is, while researchers can still not identify the moment of innovation on an internal cognitive level, in experiments like this they can pinpoint the first instance of an innovative form being produced and track its trajectory. Indeed, not only can experimenters get a full picture of who interacted with whom at what time, they can control and manipulate this to test hypotheses about the role of different social networks structures in actuation. They can also measure participants' attitudes to each other. For example, in games that involve sharing resources, the social allocation of resources can be taken as a proxy for personal attitude (e.g., Roberts 2010; this is a classic measure used in the minimal group paradigm; Otten 2016.) Furthermore, attitudes can themselves be shaped by experimenters (Kerr & Smith, 2016; Otten, 2016). Relatedly, in-game stereotypes can be established and relative prestige manipulated (cf. Sneller & Roberts, 2018). Experiments also allow researchers to get at probabilistic patterns that are difficult to get at with field data. A part of the answer to the question of why x occurred at y time and z place, but not in many other apparently similar times and places, is that x might be rather improbable. Naturally occurring data can shed light on this, but it is impossible to repeatedly reroll the dice and see how often the same change occurs. Replication, however, is a crucial part of the experimental process. Though typically framed as a means of ensuring that a particular result was not a freak event, it can also be used to shed light on which events are freak events and which happen regularly

under particular conditions. (We return to this overlap between the actuation problem and the constraints problem in Section 2.5.) In this respect computational simulations, also widely used in language evolution, and evolutionary sciences more generally, are an important auxiliary to experiments (Gong, Shuai, & Zhang, 2014; Kodner & Richter, 2019; Sneller et al., 2019), allowing the dice to be rerolled at frequencies that differ in orders of magnitude from what is possible in the laboratory.

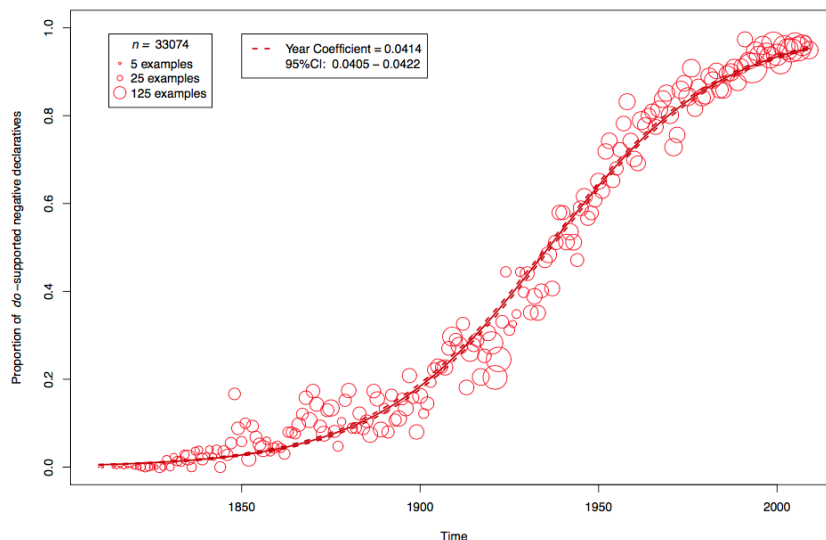## 2.2 The transition problem

Figure 2: Development of DO-support for negative possessive *have* in American English. From Zimmermann 2017 (p. 64)

The transition problem concerns the question of how a language moves from one state to another. Specific focus is given to the intervening state of the language, in order to "define the path by which Structure A evolved into Structure B" (Weinreich et al., 1968, p. 184). This problem encompasses a social and a linguistic dimension. Socially, it coincides with the propagation component of the actuation problem. In terms of Milroy and Milroy's (1985) classification scheme, we can consider the transition problem to apply to level 3 innovations in particular: those that spread beyond the immediate community of the innovator.

Work on language change in progress (e.g., Kroch, 1989; Labov et al., 1972) has found that, diachronically, change in a community takes on a stereotypically "curvilinear pattern" (Labov, 2001) or "s-curve", in which it starts slowly, reaches a point where it progresses rapidly, and then slows down again, following a logistic growth. Figure 2 displays a prototypical example for DO-support (*do not have* vs. *have not*) in American English (Zimmermann, 2017). WLH pointed out that not only does a curvilinear pattern obtain diachronically, but

that it also emerges when looking at other dimensions of change, such as across geographic space or social class. The transition problem asks how speakers in a community produce such a logistic growth pattern. One possibility is that community-level change results from "a simultaneous mutation of the grammars on the parts of great numbers of speakers" (Weinreich et al., 1968, p. 170). However, in all cases studied so far, linguists have found no evidence of speakers adhering to only the old or only the new system. Instead, we find individual speakers producing variable outputs, typically in proportion with overall community variation. These variable speakers also display style shifting, such that more formal styles exhibit a higher proportion of the more prestigious form (e.g., Labov, 1966b; Warner, 2005; Zimmermann, 2017). Here, the transition problem is concerned with precisely how a change, once actuated, spreads across geographic space, social class, and time. Theories of interaction play a major role here (e.g., Bucholtz & Hall, 2005). That change exhibits a consistent curvilinear pattern also raises the mystery of unidirectionality. How is it, once a change has begun, that it is continued in the same direction by successive generations? Here, WLH's point about peer convergence is essential: "studies of preadolescent peer groups show that the child normally acquires his particular dialect pattern, including recent change, from children only slightly older than himself" (p. 145). Labov (2007) referred to this process as children following "inherited age vectors" (p. 346), which correspond in some regard to an interaction between vertical and horizontal transmission (see Section 2.1.1), and a full understanding of how this kind of change works in language change would benefit from more consideration of this distinction, as well as with broader cultural evolutionary work on age structure (e.g., Fogarty et al., 2013, 2019; Mullon & Lehmann, 2017).

Linguistically, the transition problem is concerned with the actual state of the language in the period between the innovation of a change and its completion. At the heart of this problem is the question of whether language change is regular or idiosyncratic. The strongest view of regular language change was advanced by the Neogrammarians, who claimed that every sound change "takes place according to laws that admit no exception" (Ohstoff & Brugmann, 1878, translated in Lehmann 1967). The Neogrammarian position forms the basis of much generative and structuralist work (e.g., Bloomfield, 1933; Chomsky & Halle, 1968). In contrast to it, Wang (1969) and Wang and Cheng (1977) suggested a theory of *lexical diffusion*, arguing that sound change occurs in a lexically abrupt manner. The question of regularity can also be extended beyond sound change to other levels of the grammar: Kroch (1989) proposed a *constant rate hypothesis*, which states that the rate of syntactic change is the same across all contexts affected by the change. Labov (1981) went some way towards offering a solution to the question of regularity, outlining two primary types of change and their profiles. Regular change will exhibit a gradual shift in either pronunciation (for phonetic change) or proportion of variants used (for categorical change) in all contexts containing the variable, while idiosyncratic shift will exhibit a sharp leap for each context as they join the change one by one. An important feature of Labov's (1981) analysis is the claim that language change can be *both* predominately regular *and also* exhibit some lexical idiosyncrasy, or "words floating on the surface of sound change" (Labov, 2012). This principle is seen, for instance, in work by Fruehwald (2013), showing lexical exceptions in the otherwise regular Canadian Raising in Philadelphia, and Scobbie and Stuart-Smith (2008), showing speaker-specific lexical exceptions in the otherwise regular Scottish Vowel Length rule. A third model considers that regular sound change – that is, change affecting

all contexts containing the variable – may nevertheless show context-specific effects in how advanced each context is along the change. For sound change, word frequency has long been appealed to as a factor (Schuchardt 1885; translated in Vennemann and Wilbur 1972), and has been advocated for in usage-based accounts in recent decades (Bybee, 2002; Hay, Pierrehumbert, Walker, & LaShell, 2015; Phillips, 1984).

These three models of the regularity of language change have primarily been debated on the basis of sound change, though the Neogrammarian position is echoed in Kroch's (1989) constant rate hypothesis for syntactic change. An outstanding question in the transmission problem concerns how well each model accounts for change across all levels of the grammar.

2.2.1 Opportunities for theoretical exchange

The transition problem corresponds again to Tinbergen's Phylogeny question, being concerned with the history of a change following its actuation. Again, it has clear correspondences outside linguistics: A great deal of work in biological and cultural evolution is concerned with the history of particular changes, and how they are propagated.

There has, moreover, been a great deal of work on s-curves in the diffusion of cultural traits. Such curves occur in a very wide range of circumstances, ranging from conformist bias and wealth distributions to task structure (Henrich, 2001; Hoppitt, Kandler, Kendal, & Laland, 2010; Kandler & Steele, 2009; Laland, Odling-Smee, & Feldman, 2000). Henrich (2001, p. 993) commented that the occurrence of this curve was "One of the most robust findings from over 3,000 studies in the diffusion of innovation literature". He noted, however, that while most diffusion curves have an s-shape, a small proportion have other shapes, most commonly what he called an r-curve, which begin at a maximum rate of growth before tapering off towards equilibrium. To our knowledge, r-curves remain unobserved in linguistics, but it remains unclear if this should be taken as strong evidence for their absence.[6] If they truly do not occur in language, while occurring in other cultural domains, understanding the reason for this difference would shed light both on the meaning of s- and r-curves and on how different cultural entities evolve differently from each other. Principled engagement with different kinds of curves generally would likely be enlightening, particularly if clear conclusions could be drawn as to where s-curves occur as opposed to other kinds of curve. One possibility is that logistic growth is more strongly characteristic of language change than of many other types of cultural change. If so, this would be important to know and understand. If not, we might ask whether certain types of curve are more likely for certain parts of language. There has also been debate over the evolutionary interpretation of s-curves in language change. While they have been argued to be a signature of selection (e.g., Blythe & Croft, 2012; Stadler, Blythe, Smith, & Kirby, 2016), recent work has challenged this, arguing that they can also result from stochastic drift (Newberry et al., 2017).

There are also gains to be made from placing language change in a wider cultural-evolutionary context. While the question about regularity in change might appear to be highly language-specific, there are in fact a great many cultural entities of which analogous questions could be asked. The fundamental question underlying the linguistic one concerns

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[6]It is notable that an r-curve resembles part of an s-curve. It is possible that some apparent differences in curve shape are thus artefacts of when the data were collected, although we should be careful not to dismiss evidence for r-curves in language change on this basis.

complex cultural entities (e.g., words) composed of smaller cultural units (e.g., phonemes). Such entities are common. To take an everyday example, bicycles are composed of multiple interacting parts (such as gear mechanisms, handlebars, pedals, brakes etc.) that are themselves subject to change, in principle independently of the bikes as a whole. How, we might ask, do changes in derailleur mechanisms propagate? Alternatively, we might consider changes in complex social norms as a locus for the regularity of change. Over the last century, the way in which RSVPs are sent has changed dramatically. It seems reasonable to suppose that this change at the RSVP-level might apply across social situations, but we might also expect rates of change to vary across different types of social event, analogous to the orderly heterogeneity observed in language change (cf. Fig. 1). The point here is not to claim that all cultural change must work the same (even within language, we might expect certain types of change to be more Neogrammarian than others) but that viewing language change within a much broader cultural evolutionary context might, by allowing us to think productively about how language compares with other cultural behaviors (as opposed to thinking of it simply on its own terms, or in comparison only with other forms of communication), give us new insights that can disentangle domain-specific effects from domain-general ones (Fitch, 2010; Hauser et al., 2002).

Finally, one of the main contributions that sociolinguistics has to make to broader questions about propagation or diffusion in cultural evolution more broadly comes in the form of data. Sociolinguistic and historical linguistic data are of enormous use to scientists interested in broader patterns of cultural evolution (Jordan, 2011; Newberry et al., 2017; Scheinfeldt, Soi, & Tishkoff, 2010). Such work is most enlightening when it is linguistically well informed, and this can only come about through real dialogue and collaboration.

2.2.2 Opportunities for experimental engagement

The experiments proposed in Section 2.1.2 for the actuation problem will shed some useful light here, because of the extent to which the two problems coincide. A difficulty, however, concerns the scale of experiments typically conducted, in terms of both length and population size. Laboratory-language experiments mostly last around an hour at most and involve groups of one to four (Galantucci, 2005; Kirby et al., 2008; Sneller & Roberts, 2018). At best, population size might rise to eight (Fay & Ellison, 2013). There are good reasons for this (it is wasteful, for instance, to recruit more participants than are necessary) and such experiments are not meaningless because the groups are small. Group size matters, however (Centola, Becker, Brackbill, & Baronchelli, 2018; Raviv, Meyer, & Lev-Ari, 2019), and it matters more for some questions than others. While small-scale experiments are quite good at opening a window on actuation, the window is typically closed too soon for us to observe propagation over time, and the populations are typically too small for us to observe level-3 propagation. Iterated-learning experiments are an obvious exception in which change is tracked over multiple "generations". Even here, however, the generations themselves are typically very small indeed, so questions about within-generation population dynamics are rarely asked (though see Smith & Wonnacott, 2010, on a somewhat related question).

An important focus for future work, therefore, is to run laboratory-language experiments that are much larger in terms of both population size and timeframe. One way to do this would be to establish an online environment in which large networks of participants could

interact regularly over long periods. This kind of large-scale social-group experiment requires considerably more resources than smaller-scale experiments, but they are now possible in a way that they never were before and they would open up new vistas for investigating the transition problem (see Morin et al. 2018 for a large online communication game similar in scope to what is proposed here, though with a different focus).

Experiments can also shed light on regularity: What governs the circumstances in which a change proceeds idiosyncratically as opposed to regularly? Larger-scale social-group experiments could contribute here, but there is also room for smaller-scale experiments targeting specific hypotheses, in which such variables as the frequency of different lexical items or stereotypes associated with them can be manipulated. One significant difficulty involves the role of children. There are increasing attempts to run laboratory-language experiments with children (Kempe et al., 2015; Raviv & Arnon, 2018), but it must be acknowledged that this is challenging, and the difficulties children have with many experimental tasks may obscure the behavior of interest. The solution must be to employ a mixture of approaches. First, more efforts need to be made to validate artificial-language data by comparison with natural-language data. Second, more work needs to be conducted on a wide range of age groups; many questions are concerned not only with differences between young children and adults, but between these groups and older children, pre-adolescents and adolescents. While these age groups have become a major focus in classical artificial-language experiments within psychology and language acquisition (e.g., Hudson Kam & Newport, 2005, 2009), with recent extensions to sociolinguistic questions (e.g. Samara, Smith, Brown, & Wonnacott, 2017; Sneller & Newport, 2019), they have been surprisingly neglected in experimental language-evolution research. This is a shame, as they open vistas not available for experiments with younger children. Third, some relevant hypotheses are concerned more with how child-produced innovations propagate (and not necessarily between *young* children) than with their innovation. Experiments on this kind of question do not necessarily require that children participate; rather, child-like innovations can be simulated based on natural-language data and introduced to older participants by confederates or software.

2.3   The embedding problem

The embedding problem is, in some respects, less a problem to be solved than a call for the full contextualization of linguistic change, in both linguistic and social structure. It is concerned with the extent to which a change interacts with, and is influenced by, the structures it is embedded in.

Here, it is crucial to highlight the centrality of the linguistic variable to WLH. Change – of any type – operates over a variable, which is a structural unit within a larger linguistic structure. Taking as an example the increasing use of dorsal /r/ in Montreal French (Sankoff & Blondeau, 2007), a variable analysis would consider the change not to simply be an increase in the overall rates of [ʁ]; instead, [ʁ] can be considered one variant of the structural unit /r/ which competes with the apical variant [r]; it is the structural unit /r/ which is undergoing a change. Responding to the embedding problem involves identifying the variable, placing it in the larger linguistic structure, and then asking whether a change to the structural unit in question will result in corresponding change in other parts of the structure. Will change in the place of articulation of /r/ also result in change for other apical consonants such as /s/

and /t/, for example? Accurately identifying the variable itself is part of the difficult task of the embedding problem and has an important effect on whether additional changes to the linguistic system are considered related. This can be seen quite clearly in Labov's (1966a) analysis of postvocalic /r/ in New York City English. According to Labov (1966a), the change to higher pronunciation of postvocalic /r/ is a change in the entire vowel subsystem of ingliding vowels, rather than a change in merely the single segment of /r/; this analysis of the variable as a whole system means that we must then ask whether the change to the ingliding vowel subsystem is likely to lead to perturbations and potentially a chain shift in other vowel subsystems.

The notion of changes in one part of linguistic structure affecting other parts of it draws heavily on structuralist formulations of language change (Martinet, 1955). In fact, the embedding problem remains active within other frameworks of linguistics as well, though what is meant by "structure" may differ. In usage-based theories, where frequency plays a dominant role, for instance, the embedding problem considers how the frequency of a word or structure affects changes across all frequency values (Hay et al., 2015). Regardless of the theoretical formulation of structure, there is much evidence that structural effects of change occur; such an effect is seen in chain shifts, where a change in one vowel phoneme sets off a chain of related vowel movements (Labov, Ash, & Boberg, 2006). A finely articulated answer to the embedding problem will not only identify whether change to one part of the system may cause change to another, but also identify the rate at which this will occur.

The embedding problem also concerns embedding within social structure or "the need for social realism" (Weinreich et al., 1968, p. 176). Population-level thinking allows us to see correlations of change with social factors (e.g., age, class, style, or geography) as a crucial aspect of language change. Once we accept the linguistic variable as the unit of change and variable speakers as the mode of change, we can consider how social embedding both directs and is affected by language change. Labov (1966b) demonstrated, for example, that rates of /r/ postvocalic pronunciation in NYC are correlated with social class (across speakers) but also with style (within speakers); this gives us the *orderly heterogeneity* critical to an empirical study of language change. The embedding problem identifies these correlations, and asks how the social structure and the change might affect each other. The question of whether social factors may affect a change in progress remains a focal point in sociolinguistics, and will be taken up primarily in the context of the evaluation problem in Section 2.4.

2.3.1 Opportunities for theoretical exchange

In terms of Tinbergen's questions, the embedding of linguistic entities in linguistic structure is a matter for the mechanism question. However, the embedding problem as a whole, to the extent that it is understood as being about understanding the relationship of a linguistic entity with its (linguistic and social) environment, corresponds to the question of adaptive function (which is precisely concerned with how an entity fits into its environment). In this respect WLH's understanding of what linguistics should be is entirely consistent with evolutionary approaches. It has long been clear that genes and phenotypic traits cannot be understood in isolation from each other and must be understood as parts of a system. Similarly, much attention has been paid to interactions between cultural evolution and biological evolution (Laland et al., 2000), revealing an appreciation of the mutual embeddedness of

cultural and biological traits. There is also work in the language evolution literature on biology-culture interactions (Blasi et al., 2019; Thompson, Kirby, & Smith, 2016), as well as increasing (though controversial) attention paid to the ways in which the environment in which languages are spoken might shape their structure (e.g., Everett, Blasi, & Roberts, 2016). Insights from sociolinguistics about the social embedding and evaluation of linguistic change would add a valuable dimension to this enterprise, which has tended to lack such perspectives.

One theoretical contribution from evolutionary theory to the study of language comes in the form of Gause's competitive exclusion principle, which holds (in its original biological formulation) that two species competing for the same resource in the same niche cannot coexist without one ultimately pushing out the other (Gause, 1934; Hardin, 1960). This has already been applied to language by Aronoff (2016) and Roberts and Fedzechkina (2018) (see also Yang, 2000, for an explicit mathematical model of competition in language), although there is work to be done in clarifying the extent to which it genuinely applies to "competition" between cultural entities (as opposed to being analogically useful in some cases); if so, there is work to be done in delineating precisely what counts as a resource or niche in a linguistic or otherwise cultural context (see Altmann, Pierrehumbert, and Motter 2011 and Wallenberg 2019 for two clear examples). It does, however, seem to lend itself well to the framing of linguistic variants as elements within structural units, such that change in one variant has consequences for others. Aronoff (2016) applied it to competition in the lexicon, but it could also be applied to understanding such phenomena as chain shifts in phonology. Roberts and Fedzechkina (2018) made reference to it in the context of explaining how variants disappearing from a language might be retained if they take on a new social role (i.e., occupy a new niche).

An interesting difference in focus between sociolinguistics and language evolution concerns evolving structure. The point of the embedding problem is that features evolve as elements within structures, and that structural changes can drive evolution. Work on the evolution of structure in language evolution, by contrast, has focused on the emergence of systematicity through cultural evolutionary processes (Kirby et al., 2015; Roberts, Lewandowski, & Galantucci, 2015; Verhoef, 2012), and important connections have been made with work on the emergence of grammatical structure in new sign languages (Roberts et al., 2015; Sandler, Meir, Padden, & Aronoff, 2005; Senghas, Kita, & Özyürek, 2004). The language-evolution question and the sociolinguistic question are related: The emergence of structure relies on changes in elements that are driven by changes in other elements within the same emergent structure. Indeed, this is an area where greater communication and connection with sociolinguistics might be particularly beneficial and might shed useful light. Considerably more attention could be paid in language evolution to the details of how parts within the same system interact. Indeed, observable instances of parallel linguistic change in natural languages should raise important questions for language evolution. One example concerns initial-consonant mutation in the insular Celtic languages. This phenomenon, whereby the initial consonants of words change systematically in response to lexical and morphosyntactic triggers, is a typologically unusual feature shared by all the insular Celtic languages (Ball & Müller, 2010). Yet there is reason to think that it developed independently in the two main branches of the family (Fife, 2010). What was it about the *system* that the two branches inherited that allowed this to occur? These are questions that researchers in the field of

language evolution should care about because they get at important questions of homology and homoplasy in language, and the ways in which change is motivated and constrained by the context in which it occurs. Here again, we see the overlap in WLH's five fundamental problems, where different types of embedding may cause language change to be constrained in different ways.

2.3.2 Opportunities for experimental engagement

Of all of WLH's problems, the embedding problem is the one where sociolinguists and cultural evolutionists should most obviously already be on the same page. The problem is concerned with understanding the evolution of entities within their structural and social environments. As discussed in Section 2.3.1, however, there remain important differences of emphasis and in terms of experimental approaches, there is much to be done. In fact, experiments are to a degree inherently incompatible with maintaining full "embeddedness", relying as they do on the *isolation* of variables of interest from anything that could confound results. This – it must be stressed – is a feature, not a bug, of an experimental approach. In natural language, the fact that variation and change are embedded in linguistic and social structure makes it difficult to identify causal relationships. In an experimental setting, linguistic and social structure can be *independently* varied, enabling hypotheses about the effects of either to be tested. Principles of parallel shifting could be tested, for instance, by creating a miniature language with a minimal structure, and having a confederate introduce a change along one of two parallel features. Here, the ability to "reroll the dice" through replication further allows us to shed light on probabilistic factors in change.

Nonetheless, there remain difficult design questions with respect to how much embeddedness to bring into the lab, and how to do so. The point is not to always make experiments as similar to the real world as possible (which could easily be taken to ridiculous lengths). But if we think that any given chunk of language is necessarily embedded in a network of structures and that language is necessarily embedded in a social world, then it may be important to reflect this in the design of artificial languages. Results, furthermore, are likely to be influenced considerably by the framing of the task and the social world in which the experiment is embedded. It makes a difference to participants' behavior in communication games, for instance, to what extent they are directly interacting with other participants and the extent to which feedback occurs (Garrod, Fay, Lee, Oberlander, & MacLeod, 2007; Schober & Clark, 1989). Related points have been raised in the context of iterated-learning experiments, whose "generations" have typically consisted of single participants, although some recent work has attempted to remedy this somewhat (Roberts & Fedzechkina, 2018; Smith & Wonnacott, 2010). Along with more attention paid to differences between child and adult learning (see Section 2.2.2), this is an obvious area for future work to focus. More generally, a key question for future experimental work to address in the context of the embedding problem is this: What matters? Alternatively, what does *not* need to be taken into account? Taking the embedding problem seriously might imply that every social and linguistic feature of the environment is in principle relevant to a given change. Experimental approaches, in which the presence of such factors can be manipulated, allow us to test this.

2.4   The evaluation problem

The evaluation problem follows from the social embedding of change. This leads us to expect that "social pressures are continually operating on language, not from some remote point in the past, but as an immanent social force acting in the living present" (Labov, 1963, p. 275). The evaluation problem breaks this social pressure down into two main parts: (1) What is the nature of sociolinguistic evaluation, and (2) What is the effect of evaluation on changes in progress?

WLH reported the evaluation problem primarily in terms of overt metalinguistic evaluation, which emerges most strongly during formal portions of the sociolinguistic interview (such as reading a word list) and results in unsystematic hypercorrection. Metalinguistic evaluation was subsequently set aside as a fact that results in idiosyncratic perturbations but has no effect on the course of a change. Since WLH, much work has been done on additional aspects of evaluation. One of the most fruitful branches of this work is in the development of social meaning in practice (Eckert, 2008), which has emerged as the *third wave* field of sociolinguistics. Additional work asks whether evaluation interacts with linguistic embedding: Labov (1993), for instance, introduced the *interface principle*, the idea that social meaning attaches to surface forms (such as a specific pronunciation of *thought* as [θɑ:t]) and not structural features (such as the merged pronunciation of LOT and THOUGHT class words). There is an extensive literature on the details of how linguistic forms attract and signal social meaning (e.g., Campbell-Kibler, 2011; Eckert & Labov, 2017; Labov et al., 2011; Maddeaux & Dinkin, 2015). Social group game experiments, as outlined throughout this paper, could be particularly useful for testing hypotheses on the nature of social evaluation.

While the *nature* of sociolinguistic evaluation is interesting, it is not central to the question of language change. More fundamental is whether a change can be *affected* by social evaluation. Labov (1963) argued specifically for social evaluation playing a causal role in speakers' participation in a local sound change. Additional work (Labov, Rosenfelder, & Fruehwald, 2013; Wagner, Mason, Nesbitt, Pevan, & Savage, 2016) has demonstrated that community-wide negative social evaluation can cause a change to *reverse*. Here, the interface principle arises again as an important aspect of identifying what specifically has an effect on a change in progress. Sneller and Labov (2018), for instance, provided evidence to support Labov's (1993) argument that there are structural limits to this.

Beyond asking simply whether social evaluation might play a role in the history of a change, we can also ask how different *types* of social evaluation might play different roles in propagation. Labov (2001) outlined three types of linguistic features based on their level of evaluation: *indicators*, which are not socially evaluated, *markers*, which are, and *stereotypes*, the most overtly commented on forms that become enregistered (Agha, 2003) as intrinsically connected to a specific place, time, and social meaning. Each type of evaluation is expected to exhibit different profiles of change, with indicators proceeding uninfluenced by evaluation, markers exhibiting systematic effects of evaluation, and stereotypes exhibiting the most unsystematic effects. A likely example of this can be seen in experimental work on Philadelphia English: Traditionally, all tokens of /ɔ/ in Philadelphia English are raised and tensed, so that the vowel in *daughter* and in *water* are produced similarly. It is only the raised pronunciation of *water*, however, that is stereotyped as a feature of Philadelphia

English. In the midst of this social evaluation, the pronunciation of /ɔ/ is lowering in apparent time (Prichard, 2016). Yet it is likely that the stereotyped production of *water* as a marker of Philadelphia identity will unsystematically remain high in production. A second way of identifying different types of social evaluation can be found in the framework of indexicality (Eckert, 2008; Silverstein, 2003). Here the focus is less on how *explicit* the social evaluation is and more on how indexical orders differently signal social meaning, with first-order indices signalling group membership (such as "New Yorker") and higher-order indices signalling traits that have become associated with the group in question (such as "tough"). Given different types of social evaluation and signalling, we should expect each type to play a different role in propagation (cf. Sneller & Roberts, 2018).

2.4.1 Opportunities for theoretical exchange

Evaluation forms part of the social environment to which language (or any other cultural behavior) adapts and is thus highly relevant to cultural evolution. Like the embedding problem, the evaluation problem thus corresponds most obviously to (part of) Tinbergen's adaptive function question, although it is worth adding that linguistic evaluation is itself a cultural trait that varies across time and space, meaning that all of Tinbergen's questions apply to it too.

An explicitly evolutionary approach can be a productive way to frame evaluation in language change. Treating it as a selective force – "social selection" in Croft's (2000) terms – helps distinguish its role from neutral change (Baxter, Blythe, Croft, & McKane, 2009; Blythe & Croft, 2012; Newberry et al., 2017). As Richerson and Boyd (2005) pointed out, a crucial point that distinguishes social selection ("model-based bias" in their terms) from other selective forces is that it "depends not on the characteristics of the cultural variant itself, but instead depends on some other characteristics of individuals modeling the variant" (p. 124). This insight allows us to make sense of what Labov (2001, p. 3–34) called the "Darwinian Paradox", the fact that, while it seems right to say that language is evolving culturally and adapting to its environment, many changes that languages undergo – including those that seem selectively non-neutral – apparently run counter to communicative efficiency. The point is that communicative efficiency is merely one of several pressures acting on language (and merely one of several goals that language users have). Just as it may be adaptive for humans to engage in behaviors that will ultimately make their habitats unlivable, it can be adaptive for language to change in a way that negatively impacts the efficient communication of propositional information. Social pressures are a prominent example of this. Analogies can also be made with sexual selection in biological evolution: Traits that encourage conspecifics to mate with the bearer may not lead the bearer to live any longer.

A key desideratum for future research is to consider the evaluation problem in a broader context. Great progress has already been made in this respect in third-wave sociolinguistics, where linguistic social identity construction is viewed as part of a much more general process of identity construction involving all sorts of cultural behaviors. Indeed, this is a particularly salient area where sociolinguistics has not only data but also important theoretical insights to share with the field of cultural evolution (cf. Sneller & Roberts, 2018). An interesting question for future research concerns whether linguistic features are particularly important as bearers of social identity, as has been suggested by a number of different researchers

(Cohen, 2012; Kinzler, Dupoux, & Spelke, 2007; Nettle & Dunbar, 1997).

2.4.2 Opportunities for experimental engagement

An advantage of many laboratory-language experiments is that they allow us to manipulate social meaning in a genuinely socially engaging world. While social group games have made progress here (Roberts, 2010; Sneller & Roberts, 2018), certain questions that are highly amenable to this approach remain unanswered. For instance, there is what we might call the actuation of evaluation. How do linguistic variants acquire new social meanings? How does indexicality change? Why is it that Philadelphians are known for pronouncing water as "wooder" and not for other words with raised /ɔ/? How do particular variants rise to the level of conscious awareness? Obvious candidates for explanatory variables include frequency and salience, and these can be manipulated experimentally. As described above, in the context of the actuation problem (Section 2.1.2), a huge advantage of this kind of experiment is that we can observe every interaction and every instance of production of an artificial language. Measuring whether and when a particular variant has acquired a particular social meaning, however, is less straightforward, as changes in social meaning are not necessarily visible every time a particular variant occurs. Answering this question, therefore, requires other strategies. This might include directly asking participants which of a finite set of variants a given speaker would most likely have used and, conversely which of a set of speakers might have used a given variant (Lai, Rácz, & Roberts, under revision). Other (in some cases subtler) options are available, including matched-guise tasks in which participants are required to rate other language users on some dimension not obviously directly related to the social meaning of the variant such as how likely would they be to hire the individual (Lambert, Hodgson, Gardner, & Fillenbaum, 1960; Purnell, Idsardi, & Baugh, 1999).

Another challenge concerns the amount of time it may take for a variant to acquire social meaning. This should not be overestimated; given sufficient pressure, forms in an artificial language can acquire new social meanings in a remarkably short time (Roberts, 2010). Nonetheless, we should also be interested in observing the process in the absence of a strong pressure to mark identity. In such circumstances, experience from earlier work suggests (unsurprisingly) that things are likely to be slower. In this context, larger community experiments as proposed in Section 2.2.2 are a promising approach.

2.5 The constraints problem

The constraints problem aims to determine the set of possible changes that can occur. This is a subset of the enterprise of linguistics broadly speaking, where theoretical work in syntax, morphology and phonology aims to uncover the constraints that govern human language and distinguish possible languages from impossible ones. These constraints have been the focus of much debate on the domain-specificity of properties of language (for an overview, see Keil 1990; Fitch 2010, pp. 20–24). Here, we focus on a narrower set of constraints, stipulating that no diachronic change will result in a synchronic language that violates the overarching constraints on language, a principle that Walkden (2017) referred to as the *legality constraint*. Taking for granted that legality constraint holds, we turn our focus to the specific problem of constraints on change itself. That is, given the state of a language x, what is the set of

changes that can occur to x? We can furthermore ask how likely each change in the set is. Finally, the constraints problem must account for interactions between it and the previous four problems. For instance, language change resulting from different types of actuation, or embedded in different parts of the linguistic or social structure, may exhibit different constraints.

The first step towards resolving the constraints problem is to identify common principles of change. The fields of historical linguistics, dialectology, and typology provide an important base for this work, identifying common historical changes as well as correspondences between sister languages originating from the same mother; these patterns can help identify both the set of possible changes as well as their relative likelihood. Many examples can be found of particularly common historical changes across different areas of grammar, including resultative morphology changing to denote perfect aspect, and then to denote perfective aspect (Condoravdi & Deo, 2008); the domain-narrowing of phonological processes (Bermúdez-Otero, 2015); and SVO word order changing to SOV (Gell-Mann & Ruhlen, 2011; Kiparsky, 1996). Labov (1994) outlined a long list of proposed principles of change, each of which can be analyzed on its own and ultimately restated in terms of probabilities. Labov (1994) gave an example of this in his discussion of Garde's Principle, which holds that mergers are irreversible by purely linguistic means. Labov provided two distinct examples of unmergers in the history of English and went on to restate Garde's Principle as a *scale of relative difficulty*, which is dependent on the causes and mechanisms of reversal (ch. 11). This – identifying a principle, then identifying the probabilities at which the principle is followed – is precisely the task of the constraints problem.

2.5.1 Opportunities for theoretical exchange

In terms of Tinbergen's four questions, the constraints problem is about the limits of ontogeny, phylogeny, mechanism, and adaptive function. Like the actuation problem it is fundamental to any historical science, and there has been specific research devoted to constraints in biological evolution (e.g., Arnold, 1992; Futuyma, 2010); the field of evolutionary developmental biology is concerned with constraints at a deep level (Hall, 2012)).

Possibly the most important contribution to the constraints problem from the field of language evolution concerns what Kirby, Smith, and Brighton (2004, following earlier work by Kirby 1999) referred to as the "Problem of linkage". The crucial point is that the relationship between typological patterns in the world's languages and the cognitive biases underlying them are not linked directly; one, in other words, cannot simply be read off from the other. Rather, the relationship is mediated by cultural evolutionary processes, and understanding the origins of typological patterns requires an appreciation of these. A consequence of this is that making progress in understanding general (not language-specific) properties of cultural evolution can shed useful light on common principles identified by linguists, as well as their likelihood. Such an approach can help separate what needs to be explained in language-specific terms from what does not. A further consequence is that the cognitive biases involved in linguistic constraints, to the extent that they are amplified by cultural evolution, may be very weak (Thompson et al., 2016), which helps explain the probabilistic nature of most proposed constraints. These questions have bearing on differences between child-actuated and adult-actuated change. Some such differences doubtless result from differences between

child and adult brains; some, however, may have more to do with the different social worlds adults and children inhabit, with consequent differences in the cultural evolutionary processes involved.[7]

Conversely, work in sociolinguistics in laying out common principles of linguistic change has received too little attention in language evolution, where a deeper understanding of empirical facts about language change would be very valuable. The broader field of cultural evolution would also benefit from a clearer grasp of what we know about language – to what extent, for instance, does semantic bleaching (whereby words lose semantic specificity over time, as with the shift in words like "terribly" or "awfully" towards being all-purpose intensifiers) reflect much more general cultural patterns? To take one example, the expansion of hashtags on social media to provide not only a means of finding related posts but also a metacomment on the content of the post seems to be essentially an example of bleaching. There are other such examples, including the expansion of clothing items from their initial functional purpose into much broader fashion-related roles. Work on uniting phenomena known in language change with essentially equivalent phenomena from nonlinguistic cultural behavior is likely to be a highly fruitful enterprise.

2.5.2 Opportunities for experimental engagement

With respect to the constraints problem, the main goal of experiments should be to test hypotheses about what constrains change (such as Labov's, 1994, list of proposed principles). If it has been proposed that a particular change is impossible or unlikely because of some in principle manipulable factor, then manipulating that factor and seeing the effect on the incidence of the change in question should shine a useful light. A challenge in such experiments is to distance participants from biases deriving from their native languages; here the gold-standard approach is to sample from populations of monolingual speakers with different native languages (see, e.g., Goldin-Meadow, So, Özyürek, and Mylander 2008 and Martin, Abels, Adger, and Culbertson 2019 for two good examples). Online tools have made such experiments easier and cheaper for a certain set of questions, but experiments that need to be lab-based remain expensive in terms of both time and money, as does sampling from "non-WEIRD" populations (Henrich, Heine, & Norenzayan, 2010). For questions where language-specificity is not assumed, laboratory-language experiments employing non-linguistic modalities provide a cheaper alternative (e.g., Galantucci, 2005; Roberts et al., 2015; Stevens & Roberts, 2019; Verhoef, 2012).

As for the actuation problem (Section 2.1.2), the replicability of experiments is of great importance to the constraints problem. Because in natural language we are limited to actually occurring changes, we lack the ability to determine precise probabilities of change. With the ability provided by experiments to re-roll the dice, determining these probabilities becomes more achievable. Furthermore, as highlighted by Labov's (1994) treatment of the Garde Principle, it is possible that different types of changes exhibit different constraints. In other words, a child-innovated change may have different constraints from an adult-innovated change; socially salient changes may differ from non-salient changes. While all five of WLH's problems can be treated as distinct, a fully articulated answer to the constraints

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[7]This is not to claim that differences between adults' and children's social worlds might not themselves be related to cognitive differences.

problem must also consider the interaction of the other four problems. Here again, the ability of experiments to specifically control for factors like social meaning or age of participants provides an opportunity to specifically test how the five problems might interact.

3   Towards an integrated future

It is clear that more than one different field has been working on closely related problems from very different perspectives. As suggested in Section 1.2, this is not inherently a problem (and can indeed be a source of growth) provided the fields in question communicate with each other. In this paper we have laid out a program for what that communication might look like and what it could lead to, incorporating prospects for both theoretical exchange and new experimental tests of old problems.

Figure 3: Proposed mapping of WLH's five problems to Tinbergen's five questions

With regard to theoretical exchange, we have indicated several specific areas in which sociolinguistic work can inform work on cultural evolution, and vice versa. We have also highlighted areas in which related or analogous questions are discussed in the different fields with at times radically different emphases and assumptions. The road to genuine integration of these different approaches to these questions is not short or easy, but we firmly believe it is worth taking. We have also attempted to map WLH's five problems, fundamental in sociolinguistics, to Tinbergen's four questions, fundamental in the evolutionary sciences. This is illustrated in Figure 3. The transition problem we identified with different parts of the Phylogeny question, the embedding problem with the Mechanism and Adaptive function questions, the evaluation problem with part of the latter, and the actuation problem with parts of the Ontogeny and Phylogeny questions. The constraints problem we identified as concerning the limits of each of Tinbergen's questions. As this illustrates, the dimensions that organize Tinbergen's questions have relevance to WLH's questions too. The only one of Tinbergen's questions barely covered is the Ontogeny question (the constraints problem is concerned only with the limits of ontogeny, and ontogeny is not the primary focus of the actuation problem). The sparse coverage of Ontogeny is consistent with the sense we share

that the study of language change lacks a fully worked out theory of ontogeny. It is our hope that a more rigorous exchange between sociolinguistics and cultural evolution will play a part in remedying this. On a similar note, it might be productive for linguists to consider applying Tinbergen's questions systematically to questions of language change. Conversely, we propose that the field of cultural evolution might consider applying WLH's five problems systematically to questions of non-linguistic change.

For each of the five problems, we have also suggested specific ways in which a class of experiments more typically associated with the field of language evolution can shine valuable light. Such experiments have the potential to substantially inform sociolinguistics by providing a testing ground for theories of language change. Likewise, as we hope we have demonstrated throughout, the application of sociolinguistic frameworks and theories drawn from the study of natural language change has enormous potential to enrich experimental work on language evolution and cultural evolution more broadly. Such enrichment, however, will not occur of its own accord; it requires genuine communication and meaningful engagement. This is hard work, but worth it. The prize is a truly integrated field of language evolution.

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