Measuring the diffusion of linguistic change

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We examine situations in which linguistic changes have probably been propagated via normal contact as opposed to via conquest, recent settlement and large-scale migration. We proceed then from two simplifying assumptions: first, that all linguistic variation is the result of either diffusion or independent innovation, and, second, that we may operationalize social contact as geographical distance. It is clear that both of these assumptions are imperfect, but they allow us to examine diffusion via the distribution of linguistic variation as a function of geographical distance. Several studies in quantitative linguistics have examined this relation, starting with Séguy (Séguy 1971 Rev. Linguist. Romane 35, 335–357), and virtually all report a sublinear growth in aggregate linguistic variation as a function of geographical distance. The literature from dialectology and historical linguistics has mostly traced the diffusion of individual features, however, so that it is sensible to ask what sort of dynamic in the diffusion of individual features is compatible with Séguy's curve. We examine some simulations of diffusion in an effort to shed light on this question.

Keywords: linguistics; dialects; diffusion

1. INTRODUCTION

We summarize our key contributions in this introductory section, and provide a guide for the rest of the paper.

(a) Key contributions

There are two core contributions of the present paper. First, we extend arguments made by Nerbonne & Heeringa (2007) that dialectometric models provide a means for measuring linguistic variation in the aggregate and thence a means for measuring the influence of geography (and other factors) on linguistic variation. We extend these arguments by recalling Séguy's early demonstration that there was a sublinear relation between geographical distance and lexical variation, and then by examining six novel datasets, all of which confirm the relationship, which we propose dubbing SÉGUY’S CURVE.

But we also ask how we might engage the sociolinguistic literature, which has reflected profoundly on the mechanisms of diffusion, and the current exercise in measuring linguistic variation. We therefore turn secondly to a novel simulation of linguistic diffusion in which we can manipulate the strength of accommodation owing to geography. The results of the simulation suggest that the attractive force owing to gravity decreases linearly with distance, and not quadratically as the gravity model proposes.

(b) Structure

Section 2 reviews some of the linguistic literature on the geographical diffusion of language change, in particular, Trudgill’s GRAVITY MODEL. Our point in this review is to note the need for a way of measuring diffusion and the influence geography has on it. Section 3 provides a very brief introduction to dialectometric techniques for measuring linguistic differences, and introduces SÉGUY’S CURVE of linguistic variation as a function of geography. Section 4 then reviews two recent papers exploring the gravity model using dialectometric techniques and extends their empirical base by examining six other datasets, reporting on the percentage of linguistic variation which can be explained by geography, even those which may not represent relatively stable settlements in which we can be sure that diffusion has worked ‘normally’. Section 5 then introduces simulations as a tool to explore the relation between the diffusion patterns of individual lexical items and those of large aggregates, drawing the conclusion that the attractive power of geography is more probably a linear force than an inverse square relation of the sort proposed by the gravity model. Finally, §6 wraps things up a little, and also suggests why the ideas discussed here may be of more general interest for researchers interested in the determinants of linguistic diffusion.

2. THE SOCIOLINGUISTICS OF DIFFUSION

There is a substantial linguistic literature on diffusion which has documented and explained a large number of cases where individual features have spread, and most of the recent work has come from sociolinguists. We review this before turning to the aggregate analyses that have arisen in dialectometry.

(a) The wave theory

The locus classicus for linguists’ discussion of diffusion is Schmidt’s (1872) demonstration that there are important features that cut across the hierarchical classification of the Indo-European languages (Bloomfield 1933, pp. 312–319). Bloomfield uses Schmidt’s demonstration to argue that in addition to
cases of sharp divisions between languages demonstrated by regular correspondences and modelled by family trees of relatedness, there must also be regular processes of diffusion even between the branches of the family trees, i.e. even between differentiated varieties (Bloomfield 1933, pp. 318). Bloomfield believed that speech habits were modified throughout life each time an individual entered into communication with another (Bloomfield 1933, pp. 46). He, therefore, predicted that processes of diffusion would follow the lines of communication density (Bloomfield 1933, pp. 46, 326) so that lines of dialect differentiation, reflecting processes of diffusion, should ultimately be explained by the density of communication. The idea is that diffusion is enabled and promoted by more frequent communication.

(b) The gravity model

Peter Trudgill’s GRAVITY MODEL effectively recast Bloomfield’s notion of density, focusing on distance and population sizes as predictors of the chance of communication (Trudgill 1974). In these models, inspired by social geography, the spread of linguistic innovation is always via social contact which is naturally promoted by proximity and population size. The gravity model foresees linguistic innovations not simply radiating from a centre, as they might in a pure version of the wave theory, but rather affecting larger centres first, and from there spreading to smaller ones, and so on.

In the special case of landscapes with a few larger-size cities, an innovation may spread from one large population centre directly to another immediately sized one, often by-passing smaller, geographically intermediate sites. This is owing to the role of population size. Innovations are no longer seen as rolling over the landscape uniformly as waves, but rather as passing over immediate small neighbours in favour of larger, potentially more distant settlements. For this reason it is also referred to as a CASCADE model (Labov 2001, p. 285): linguistic innovations proceed as water falling from larger pools to smaller ones, and thence to smallest. Each population centre may be seen as having a sphere of influence in which further diffusion proceeds locally.

The connection to physical gravity may be appreciated if one considers the solar system, i.e. the sun, the nine planets and their moons. In understanding the movements of a given heavenly body, it is best to concentrate on the nearest very massive body. For example, even though the moon is affected by the sun’s mass, its rotation is determined almost entirely by the much closer Earth. The physical theory of gravity accounts for this by postulating a force owing to gravity which is inversely proportional to the square of the distance between bodies. In this way very distant bodies are predicted to have much less influence than nearby ones.

There have been many reactions to the gravity model which we cannot elaborate on here for reason of space. We refer to our earlier paper (Nerbonne & Heeringa 2007) for discussion. In summary, research has been mixed in its reception of Trudgill’s postulation of a gravity-like effect in linguistic diffusion. There have been voices of affirmation, but also of dissent.

This essay concentrates on the effect of geography, rather than population size, as both Nerbonne & Heeringa (2007) and Heeringa et al. (2007) show that geography is by far the more important factor. In contrast to most of the literature on this topic, this essay aims to measure the influence of geography on language variation in order to contribute to the discussion. Other contributions attempt no quantitative assessment of the strength of the influence, while this is possible and worthwhile. They also all require methodologically that the researchers identify one or more ongoing linguistic changes and find a way to track them, which is likewise non-trivial. We shall instead examine the residue of a large range of changes in a number of different language areas.

3. AGGREGATE (DIALECTOMETRIC) VARIATION

The remainder of this paper explores an alternative approach to studying the influence of geography on diffusion. We proceed from techniques for measuring linguistic variation, immediately obtaining the advantage of then being able to measure the influence of geography using standard (regression) designs. We shall aggregate the differences in many linguistic variables in order to strengthen their signals. We also assume that all the variation we encounter is the result of diffusion—even if we cannot identify its source. This makes it easier to apply the techniques without first studying where changes are occurring and in what direction.

But before presenting dialectometric approaches to diffusion, it is worthwhile reviewing how and why linguistic distances are measured. We do not have the time or space to review all of the background or range of techniques here, so the presentation will be sketchy. Fortunately, there are good introductions available (Goebl 1984; Heeringa 2004; Goebl 2006; Nerbonne 2009; Nerbonne & Heeringa 2009).

Roughly, dialectometry attempts to distil the aggregate relations from among a set of sites by systematically comparing a large set of corresponding linguistic items (Nerbonne 2009) and measuring differences. By aggregating over a large set of corresponding items, the dialectometric procedure attempts to immunize its work against the dangers of fortuitous, or biased selection of material.

The simplest dialectometric procedures analyse linguistic variation at a nominal or categorical level (Goebel 1984), at which linguistic items are either identical or not. Non-identical items contribute to the linguistic distance between sites, while identical elements do not. Various weighting schemes may be employed, as well (Nerbonne & Kleiweg 2007). Dialect similarity (s) is assayed as the fraction of overlap in the sample, and dialect dissimilarity (distance) is simply the inverse, d = 1 − s.

Our own developments in dialectometry have emphasized the advantage of applying LEVENSHTEIN DISTANCE, also known as EDIT DISTANCE, to phonetically transcribed data. Heeringa (2004) and Nerbonne (2009) present these techniques in more detail, so that we may summarize here that the techniques enable us to measure differences in pronunciation at
a finer level than merely ‘same’ or ‘different’. Instead
the technique aligns the phonetic segments in a pair
of word pronunciation transcriptions optimally and
sums the differences between the segments in an opti-
mal transcription. We illustrate the procedure via two
aligned strings, one a transcription of the pronunciation
of the word ‘afternoon’ in the American south, and
the other a transcription of its pronunciation in
the American north (or Midland):
æ ə f t æ ə n u n
æ ø f t æ r n u n

The optimal alignment reveals three points of mis-
mismatch, one substitution of one version of [u] for
another, one insertion of [ɹ] creating an initial diphthong
and one deletion of a syllable-final [r]. Each of these points of mismatch is associated
with a cost, and the total cost is regarded as the phonetic
distance between the two pronunciations.

As Nerbonne (2009) shows, the procedure
normally results in a consistent measure of pronunciation
difference (Cronbach’s α > 0.80 with at least 30
words in the sample), and the procedure has been vali-
dated with respected to dialect speakers’ judgements
of dialect distance with the result that measurements
 correlated well with judgements r ≈ 0.7 (Gooskens &
Heeringa 2004).

We shall examine various dialectological situations
below, all of which were examined using either the
nominal level of analysis pioneered by Séguy (1973)
or Goebel (1984) or the numeric level as realized by
Levenshtein distance.

(a) Séguy’s curve

The founder of dialectometry, Séguy (1971) examined
the distribution of lexical distance, measured categori-
cally (same or different variants) in the very first
publication in this direction ‘La relation entre la dis-
cance spatiale et la distance lexicale’, and he compared
the resulting curve with the one in which lexical distance varied with the square root of the log-
arithm of geographical distance. The result, as one
might imagine, is a curve that shows an initial rise
and then becomes quite flat. We show Séguy’s distri-
bution in figure 1. In view of Séguy’s very early work
in this direction, I propose that the sublinear curve
of linguistic distance versus geographical distance be
called SÉGUY’S CURVE.

Since Séguy (1971) appeared a little before Trudgill
(1974), there was apparently never any early attempt
to confront the two views of how geography influences
linguistic variation until recently. The task of the fol-
lowing sections will be to show what these two views
have to do with one another.

Séguy’s insight is comparable to that of population
geneticists, who had earlier found the same sublinear
distribution of genetic diversity when viewed as a function
of geography, a phenomenon they have come to call ‘iso-
lation by distance’ (Jobling et al. 2004), tracing the idea
back to work in mathematical biology of the 1940s and
1950s (Wright 1943; Malécot 1955). More recently,
Holman et al. (2007) have examined the relation
between geographical distance and typological distance
as assayed by a set of structural features, referring to
their results as establishing ‘spatial autocorrelation’.

4. A DIALECTOMETRIC VIEW OF GRAVITY

Nerbonne & Heeringa (2007) and Heeringa et al.
(2007) applied dialectometric designs to questions of
diffusion in an attempt to add an aggregate quantita-
tive perspective to the discussion, claiming two
advantages for dialectometric approaches in approach-
ing this question. First, some researchers may have
relied on fortuitously chosen features which corrobo-
rate or contradict the lasting influence of geography
and the chance of social contact, but which might be
atypical. Dialectometry proceeds from the measure-
ment of a large number of linguistic variables, and
thus affords the opportunity to examine Trudgill’s
ideas from a more general perspective. Second, dialec-
tometry enables the research to quantify the strength
of attractive forces at least somewhat, and thus move
beyond cataloguing examples which appear to obey
or contradict the predictions of the theory.

Nerbonne & Heeringa derived linguistic distances
from 52 towns in the Lower Saxon area of the
Netherlands using a technique explained above ($§3$);
they then attempted to explain the linguistic distances
on the basis of geographical distance and the chance
of social contact as reified in population size. Using a
multiple regression model, they proceed from
Trudgill’s formulation of the gravity model:

\[ I_g = s \cdot \frac{P_i P_j}{(d_{ij})^2}, \]
where $I_i$ represents the mutual influence of centres $i$ and $j$, $P_i$ is the population of center $i$, etc. and $d_{ij}$ is the distance between $i$ and $j$. $s$ is a constant needed to allow for simple transformations, but it may be viewed as ‘variable expressing linguistic similarity’. It will of necessity be ignored in what follows. See Nerbonne & Heeringa (2007) for discussion.

The model predicts that the ‘attractive’ (accompromidating) force should correlate inversely with (the square of) geographical distance, and directly with the product of the population sizes. Reasoning that linguistic distance should reflect this attractive force, but inversely, Nerbonne & Heeringa (2007) examined whether linguistic distance therefore directly correlates with (the square of) geographical distance and inversely with the populations’ product, and found that there appears to be no effect of population size on linguistic distance, but also that linguistic distance indeed correlates directly with geographical distance. But Nerbonne & Heeringa also noted that the correlation between geographical and linguistic distance appeared not to be quadratic, as the gravity model predicts, but rather sublinear, i.e. in the same family of relations that Séguy noted in 1971. The best predictor of aggregate linguistic distance was not the square of the geography, but rather the logarithm.

Heeringa et al. (2007) criticized the choice of sites in the Nerbonne & Heeringa study, replacing these with a set of sites from the entire Dutch area (Nerbonne & Heeringa had worked exclusively with Lower Saxon) which included rather more settlements of large population size. This study replicated the fact that aggregate linguistic distance depends in a sublinear fashion on geographical distance, but it vindicated the gravity model in showing that population size indeed played the role predicted. In the later study, population product size accounted for six per cent of the variance in linguistic distance.

(a) Séguy’s law

Given Séguy’s early demonstration that French lexical variation depends sublinearly on geographical distance, and Nerbonne & Heeringa’s (2007) replication of this result for Dutch pronunciation, it is worth examining a range of other studies to see that they may contribute to the discussion.

Alewijnse et al. (2007) obtained pronunciation data from Bantu data collected in Gabon by researchers from the Dynamique du Langage (http://www.ddl.ish-lyon.cnrs.fr/) in Lyon. Let us note that since the Gabon Bantu population consisted of migratory farmers until recently, it might not be the right sort of population for this study as the relative mobility of the population might disturb the traces of ‘normal diffusion’. The data involve broad phonetic transcriptions of 160 concepts taken from 53 sampling sites. Tone was not analysed as the Bantu experts were skeptical about how reliably it had been recorded and transcribed. The geographical locations recorded were those provided by native speaker respondents, but they should be regarded in some cases as ‘best guesses’ considering that the population has been fairly mobile (over long periods of time). The pronunciation differences were analysed using the procedure sketched in §3, and these correlate strongly with logarithmic geographical distances ($r = 0.469$).

Prokić (2007) obtained data on Bulgarian dialectology from Prof. Vladimir Zhov’s group at St Clement of Ohrid’s University of Sofia. Prokić worked on broad phonetic transcriptions of 156 words from 197 sampling sites in Bulgaria. Palatalized consonants, which are phonemically distinct in Bulgarian, were represented in the data, but stress is not. The pronunciation difference measurement of §3 was applied, where alignments were constrained to respect syllabicity so that vowels only aligned with vowels and consonants only with consonants. Since Bulgaria was occupied by Turkey for several centuries (until 1872), its linguistic variation may display less reliable patterns vis-à-vis geography. The correlation of pronunciation and logarithmic geographical distance was measured at $r = 0.488$.

Nerbonne & Siedle (2005) obtained data from the Deutscher Sprachatlas in Marburg (http://www.uni-marburg.de/fb09/dsa/). The pronunciations of 186 words had been collected at 201 sampling sites for the project Kleiner Deutscher Lautatlas. A team of phoneticians transcribed the data narrowly; each word was transcribed twice independently and disagreements were settled in consultation so that there was consensus about the results. The pronunciation difference measurement of §3 was applied, where alignments were constrained to respect syllabicity so that vowels aligned only with vowels and consonants only with consonants. Logarithmic geographical distance correlates strongly with pronunciation in this dataset ($r = 0.566$).

Kretzschmar (1994) reports on the LAMSAS project (http://hyde.park.uga.edu/lamsas/), conceived and carried out mainly by Hans Kurath, Guy Lowman and Raven McDaid in the 1930s and again in the 1950s and 1960s. The data are publicly available at http://hyde.park.uga.edu/lamsas/. Due to differences in fieldworker/transcriber practices, we analyse only the 826 interviews which Guy Lowman conducted in the 1930s involving 151 different response items. LAMSAS used its own transcription system, which we converted automatically to X-SAMPA for the purpose of analysis, which was conducted using the measurements described in §3. Nerbonne (in press) describes some aspects of the analysis in more detail, in particular the degree to which phonological structure is present. Since the area of the present USA has only been English speaking for the last several centuries, it may retain traces of migration disturbance in the geographical distribution of linguistic variation. We nonetheless measured a strong correlation between pronunciation and geographical distance after applying a logarithmic correction to the latter ($r = 0.511$).

Wieling et al. (2007) analyses the data of the projects Morphologische Atlas van Nederlandse Dialecten (MAND) and Fonologische Atlas van Nederlandse Dialecten (FAND; Goeman & Taeldemann 1996). In order to eschew potential confounds owing to transcription differences Wieling et al. (2007) analyse only the data from the Netherlands, and not that of Flanders. The former included 562 linguistic items from 424 varieties. Since the Netherlands comprises only 40 km$^2$, the MAND/FAND is one of the densest
dialect samplings ever. The pronunciation differences were assayed using the technique described in §3, where alignments were constrained to respected syllabicity. Pronunciation distance correlates strongly with the logarithm of geographical distance ($r = 0.622$).

Gooskens & Heeringa (2004) analyse the variation in 15 Norwegian versions of the fable of the International Phonetic Association, ‘The North Wind and the Sun’, making use of material from http://www.ling.hf.ntnu.no/nos/. The material was again analysed using the pronunciation difference measurements in §3. Norwegian distinguishes pronunciations using lexical tone, and Gooskens & Heeringa experimented with measurements which incorporated this, with little distinction in the overall (aggregate) results. Interestingly from a geographical point of view (Britain 2002), Gooskens (2004) compares two geographical explanations of the linguistic differences, one based on ‘as the crow flies’ distances, and another based on the (logarithmic) travel time estimates of the late nineteenth century, showing an improvement in correlation (from $r = 0.41$ to $r = 0.54$). The motivation for examining the two operationalizations was naturally that Gooskens expected travel time to be the better reflection of the chance of social contact.¹

We conclude from this section that there is a simple, measurable and normally sublinear influence which geography exerts on aggregate linguistic differences (figure 2). It is an empirical finding, not a theoretical prediction, that geography accounts for 16 per cent to about 37 per cent of the linguistic variation in these datasets ($100 \times r^2$). We note that the potential disturbances caused by migration, occupation, and recent settlement appear insubstantial enough in the cases examined so as not to disturb the overall tendency first noted by Seguy, namely that variation increases as a sublinear function of geography.

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Figure 2. Six examinations of the influence of geography on linguistic variation; a logarithmic curve is drawn in every case. The $y$-axes vary owing to details of measurements, but all are linear scales. See text for details.
should also note that Spruit (2006) obtains a slightly better analysis using a linear rather than a sublinear geographical model to explain syntactic distance, but we shall not pursue the issues this suggests here.

5. INDIVIDUAL VERSUS AGGREGATE DIFFERENCES

Taking stock a little, we note that the substantial socio-linguistic literature on diffusion has on the one hand recognized a major role for social contact and therefore geography, but has concentrated on identifying additional, what we might call ‘extra-geographical’ factors. Its data collection and analysis have exclusively concerned the patterns of diffusion found in individual linguistic items such as individual words or sounds.

The dialectometric view on the other hand enables the measurement of the influence of geography on aggregate variation. Is there any way to bring these two perspectives to a more rewarding engagement?

We can think of two ways of exploring the relation between the individual variation discussed in the scholarly literature reviewed in §2 and the aggregate dialectal variation presented in §3, one empirical and the other simulation-based. The empirical path is conceptually simple, and involves examining the distributions of a large number of individual items to explore how their distributions are related to the aggregate distance curves of §4. As conceptually simple as that strategy is, still it requires identifying a large range of words, sounds, etc. about which there would be agreement that they constitute units of diffusion. This could be quite difficult.

But we can also simulate the diffusion of individual linguistic items to obtain insight about the relation between the diffusion of individual items and the aggregate diffusion curves examined in §4a. We turn now to a description of a simulation.

(a) Simulating diffusion

We wish to examine the effect of the ‘gravity’-like, attractive force which influences diffusion, and we shall restrict our attention to the influence owing to geography, continuing to ignore the influence of population density. Like Holman et al. (2007) we created simulations in order to focus on the contribution of individual factors, in our case the relation between aggregate linguistic distance and the effect of attractive forces of varying strengths on individual linguistic features.

To investigate this process via simulation, we create several thousand sites, each of which is represented by a 100-dimensional binary vector. The sites are at regular distances from a single reference site so that the most distant site is several thousand times more distant from the reference site than the closest is. The 100 dimensions may be thought of as 100 linguistic items, e.g. 100 words or perhaps 100 pronunciation features, such as the pronunciation of the vowel in a words such as ‘night’ (i.e. as [næt] in the American south versus [næt] in standard American). The value ‘0’ indicates that the site is the same as the reference site with respect to a given dimension, and ‘1’ indicates that it is different. We intend to be deliberately vague about the units of diffusion. We proceed from the assumption that we are observing the differentiation of an initially homogeneous community, but we add some noise in the form of 100 random chances at change at every site. Unchanged linguistic items are assumed to be identical to those at the reference site. Since we finally compare each value in a given dimension only with other values in the same dimensions, we make no special assumptions about what these values are.

In reality, each settlement in a sample may potentially be influenced by any other sample, as Holman et al. (2007) note, but we wish to keep the simulation simple, so we shall examine the situation in which all the influence is exerted by a single reference site. The simulation will vary the strength with which that influence is exerted. We wish to contrast two possibilities concerning the strength with which the reference site influences others. In the first linear view, the distance of the simulation site predicts directly the chance with which the value of the reference site is adopted. In that case a site that is \(d\) distant from the reference site has twice the chance of being like it (with respect to a given linguistic dimension) as a site that is \(2d\) distant. In the second quadratic view, a site that is \(d\) distant from the reference site has four times the chance of being like the reference site when compared with another that is \(2d\) distant. The latter is the view advanced by the gravity model.

To simulate the diffusion of linguistic change we iterate once through the set of sites. At each site, we repeat the process of random change \(n\) times, where \(n\) depends on the distance of the site from the reference site. In the linear model \(n\) depends directly on the distance to the reference site, and in the quadratic model of influence \(n\) depends on the square of the distance. The random change itself is quite simple. We randomly select one dimension \(i\) in the 100-element vector, then generate a second random number, this time between 0 and 1. If the number is greater than 0.5, then we set the \(i\)th position to 1, indicating that the site differs from the reference site at dimension \(i\). If the number is 0.5 or less, then the value of the \(i\)th dimension at the site is set to 0, indicating that it is linguistically the same as the reference site. (We note that it is distinctly possible that the same dimension is randomly chosen more than once when there is a large number of repetitions of the random change. In this case changes may cancel each other out.) In all cases the aggregate distance of the site from the reference site is simply the sum of the vector over all positions.

So the overall effect is that sites near the reference site have few changes of changing—the influence of the reference site is too strong. Sites twice as distant have twice as many chances to change, and, in the case of the ‘gravity’-inspired simulated, four times as many. In both cases changes are introduced randomly, but while the chance of a change being attempted depends linearly on the geographical distance from the reference point in the linear model, it rises quadratically with the geographical distance in the quadratic model. Furthermore, since the stochastic events of change are competing for the same limited number of linguistic dimensions, the more distant sites are also more liable to change and also change back.
Results of simulations

Figure 3 compares the results of two single runs of the simulation, one in which the chance of change rises linearly in the distance to the reference point, and a second in which the same chance of change rises quadratically. In both cases we have drawn the logarithmic regression line, for which we obtain $r = 0.66$ (linear attraction) and 0.71 (inverse quadratic attraction), and in both cases we appear to obtain the characteristically sublinear Séguy curve of aggregate linguistic distance.

The curve in figure 3b appears somewhat sigmoidal, however, a suspicion we examine more closely by applying local regression to the same dataset. The result of the local regression is shown in figure 4, and, indeed, it appears that the quadratic influence results in a different curve in this respect. Local regression lines do not differ significantly from logarithmic lines in the other scatterplots (the left plot of cumulative linear influence in figure 3 or in any of the plots in figure 2).

Although the results clearly point to a linear effect of geography on the likelihood of an individual linguistic item differing from that of another site, we acknowledge that further simulations would be useful to be certain of the influence of some parameters, including the relatively great distance used at initialization, the effective ceiling of 50 per cent on average differences caused by restricting the model to binary choices, and the relatively constant variance in the simulations. Finally, it would be useful to view simulations in which locations interacted with each other and not merely with a single reference point. Holman et al. (2007) have analysed simulations with lattice structures with respect to other research questions.

6. CONCLUSIONS AND FUTURE WORK

Our foremost conclusion is that we can effectively test models of diffusion quantitatively, and, in particular, that these may be tested on the basis of large aggregates of linguistic material. This avoids the danger of picking material fortuitously, and it obviates the need to find material in the process of change.

We likewise conclude on the basis of several empirical studies that the chance of social contact, operationalized through geography, can account for...
about one-quarter of the aggregate linguistic variation we find in large collections such as dialect atlases. Our experiment in simulation suggests that the attractive force which tends to resist linguistic change decreases linearly with geographical displacement while the gravity model suggests an attractive force that would decrease quadratically with geography. It would clearly be valuable to seek empirical data on individual linguistic variables with which the diffusion model might be tested.

If this approach to analysing diffusion is sound, and assuming that the relevant variables can be operationalized and that suitable data can be found, then this approach should likewise open the door to studies on the influence on non-geographical factors. These might be compared with geography. As the brief remarks on travel time (§4a) might suggest, it is also possible to examine alternative conceptions of geography, taking a step in the direction urged by Britain (2002).

Peter Kleiweg was responsible for all the programs used in this paper, in particular, the dialectometric package L04 (http://www.let.rug.nl/kleiweg/L04/). Two anonymous referees were generous in their comments.

ENDNOTE

1Van Gemert (2002) also examined the use of travel time in predicting Dutch dialect distances, but it turned out that travel time correlated nearly perfectly with geographical distance in the Netherlands, which lack the fjords and mountains that impede direct lines of travel in Norway.

REFERENCES


