The World Language Problem

Jonathan Pool

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Antagonists in the ancient controversy over world multilingualism agree that a successful artificial language must overcome a coordination problem: to motivate learners when few speak the language. It is believed a take-off point must be reached, after which the spread of such a language would be self-sustaining. This problem may also frustrate other linguistic and nonlinguistic innovations. The dynamics of recruitment and defection, however, render a take-off point analysis dubious. A simple model of artificial-language evolution supports this doubt. Despite low learning cost, universal competence in an artificial language, if achieved, might be unstable. More generally, any degree of penetration by an artificial language, from 0% to 100% of the world population, might be stable. The results help interpret the fact that the artificial language movement is small yet stable, frustrated yet complacent, and convinced that language choice is a social dilemma that needs coordination to prevent a deficient outcome.

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Jonathan Pool
University of Washington

The idea of a single language known and used by the entire human species is ancient and recurring. It appears in the Old Testament, in ancient Persian philosophy, and in writings of More, Bacon, Comenius, Descartes, Leibnitz, Condorcet, Fourier, Comte, Baha'u'llah, Engels, Spencer, Tolstoy, Nietsche, Ostwald, Sapir, Bloomfield, Boas, and Mead (Dratwer 1977; Large 1985, 3–63, 183; Laycock and Mühlhäusler 1990; Mead and Modley 1967).

While some have advocated the universal use of a classical or contemporary natural language, others have decided that a world needs an invented language, and about a thousand persons have actually tried to invent one

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(Dulič̆enko 1988). The inventors have typically envisaged a world in which their language would be everyone's second language and would be used in translingual communication, supplementing but not replacing existing natural languages. For this use, it has been claimed that artificial languages, when compared to natural languages, are more (a) learnable (because of grammatical and lexical regularity), (b) powerful (having true-to-nature terminologies, logical structures, and freedom from idiomatic restrictions), and (c) fair (having no native speakers).

Despite these purported advantages of an artificial world language, only five such languages seem to have ever acquired communities of speakers: Volapük, Esperanto, Ido, Occidental, and Interlingua (Blanke 1985). The most successful, Esperanto, has fallen far short of universality, having at no time been known or studied by more than about 0.002% to 0.05% of the world population (Forster 1982, 16–40; Piron 1989, 157).

What is the problem of artificial world languages? Is there no need for a world language? Is there a need, but not for an artificial language? Is there a need for an artificial language, but a need met by none of the languages so far invented? Or are some of the invented languages suitable, yet blocked by a problem of coordination—getting the potential learners of an artificial language to agree on which one to learn and overcoming the fact that there is little value in learning it when few have yet learned it?

There is no consensus on whether a unique world language would be beneficial. While the multiplicity of languages used in international relations makes some complain of information loss (Large 1983) and translation cost (King 1977), it comforts others who seek to prevent the hegemony of a single polity or culture (e.g., Mazrui 1976, 473–79), and it does not concern still others who assume that language barriers are not as serious as they superficially seem (e.g., Farb 1974/1975, chap. 16).

Among those who favor a unique world language, some prefer a major natural language (such as English), others a minor natural language (such as Armenian), and still others an artificial language (such as Esperanto). Major natural languages are already widely known and have well-developed literatures, vocabularies, and stylistic norms. Minor natural languages privilege only a small number of native speakers. Artificial languages have the claimed advantages of learnability, power, and fairness, of which the learnability (Columbia University 1933, 6–7; Pool 1981, 157) and fairness (Lenneberg 1957) claims have some empirical support but the power claim remains undemonstrated (Pool and Grofman 1989).

But even those who disagree on these questions tend to agree that artificial languages face a particular coordination problem. It is not the problem of

agreeing on which artificial language to learn. New learners have overwhelmingly gravitated toward whichever artificial language is currently most popular. Rather, it is the problem of motivating learners to learn a language that will not give them substantial rewards until and unless many others subsequently learn it (Large 1985, 182, 200–1; Laycock and Mühlhäusler 1990, 863–64). Zamenhof, the inventor of Esperanto, appreciated this problem. On the title page of his 1887 textbook, he placed a still-quoted motto: "*Por ke lingvo estu tutmonda, ne sufiĉas nomi ĝin tia*" ("One must do more than call a language universal to make it universal"). At the end of the book, he included returnable "promise forms," obligating the signer to learn Esperanto whenever 10 million persons had made the same promise. He also invited readers to waive this condition if they were willing to do so (Boulton 1960, 33, 38). One explanation for Esperanto's relative success is that while the inventors of rival languages concentrated on perfecting their rules, Zamenhof spent his time mobilizing users and providing them with an extensive library of great literature (Jordan 1987). If this was still not enough to make Esperanto conquer the world, the coordination problem seems to be at fault. Promoters of Esperanto often report that when they try to persuade someone to learn it they get a response like "Yes, it's a great idea, but it's too bad it never caught on." In public opinion polls, a majority usually approves the idea of a simplified world language, but only a small minority ever learns one (Large 1985, 197–98). Esperantists describe *la fina venko* (the ultimate victory) as their goal, implying that there is some degree of penetration that will render the universality of Esperanto self-sustaining.

The obstacle to an artificial language's spread may be an extreme case of a coordination problem impeding any linguistic change: the rewards are conferred on those who make the same choices everyone else is making. Changing to a different common language appears difficult, even if all would benefit from such a change; conversely, such a change, once made, is difficult to reverse. This understanding is perhaps reflected in knife-edge legends about English having become the dominant language of the United States and Hindi the national language of India by one-vote margins (Kloss 1977, 28; Laitin 1989, 433).

In turn, this characteristic of language choice may apply to an even wider class of choices. Converting the United States to the metric system may be an improvement for all, but one that few are willing to adopt until most others have done so. The Dvorak typing keyboard is rarely used, despite the reported evidence that only a few days of its use can speed typing enough to repay the relearning cost (David 1985).

The understanding of the world language problem as—at least in part—a

coordination problem seems compelling, but it may be a misunderstanding. It is possible that an artificial language with many speakers would be no more successful at achieving universality than an otherwise identical artificial language with few speakers. It is even possible that an artificial language that is already universally known would lose speakers, despite its universality, and return to its former rarity or even to oblivion.

There are empirical reasons for this skepticism. One is that pockets of linguistic isolation persist even in the heartlands of the world's major languages, such as the United States, France, and the USSR. Another is that several languages—Sumerian, Akkadian, Aramaic, Greek, Latin, French, and English—have successively attained near-universality in international diplomacy (Ostrower 1965, vol. 1), leading one observer to conclude: "If anything is clear from the history of international communication, it is that once a language has established itself as predominant in the world it will eventually fall from that perch. There is no reason to suppose, moreover, that this will not happen to English as well" (Noss 1967, 59). A further reason is that in the 1890s, nearly all the speakers, numbering perhaps a million, of the preeminent artificial language, Volapük, abandoned it, many flocking to the newly invented Esperanto (Jordan 1987).

There is also a theoretical reason for doubting the coordination-problem interpretation. People may differ in their ability to learn an additional language and in the benefit they would get from knowing it. Those who can learn it most easily and those who can benefit most from knowing it may tend to be the ones who learn it first. If so, then as an artificial language acquires more speakers, the remaining nonspeakers may be increasingly difficult to recruit. Conversely, the more speakers it has, the more holding power it may have, but the more holding power it may also need in order to hold its more defection-prone recent learners.

In the next section, I spell out this theoretical reservation by modeling the struggle of an artificial language for worldwide acceptance. My goal is to demonstrate a flaw in a usually unquestioned belief that the problem of an artificial world language is to reach a threshold number of speakers (a take-off point), beyond which its further expansion will be self-sustaining. Given this limited goal, I confine myself here to a special case that is just complex enough to examine some conditions for the existence or nonexistence of a take-off point.

THE MODEL

ASSUMPTION 1

The *world* is partitioned into two continuous *groups*, each with a positive *size* and a different *native language*. Each group's native language is the other group's *foreign language*. The sum of the groups' sizes is the *population*.

Motivation. This model simplifies the linguistic world by assuming that each person is an infinitesimal fraction of the population of a group, that each person is natively monolingual, that languages are discrete rather than points on continua, that there are only two native languages, and that the political organization of the world into states is irrelevant. All these assumptions are simplifications of the known facts, but they still leave room for a coordination problem to arise or be absent.

ASSUMPTION 2

There is one *artificial language*. It is neither group's native language.

Motivation. I am ignoring here the minor problem of agreeing on which artificial language, if any, one should learn. I am also assuming that there cannot be native speakers of artificial languages; there are, in fact, no more than a few hundred such persons in the world.

ASSUMPTION 3

Each set of languages that includes a group's native language is a *language alternative* for the group. In each group, each person has exactly one *language repertoire*, drawn from the group's language alternatives. The fraction of each group having each language repertoire is measurable.

Motivation. Although people sometimes forget their native languages, I ignore this phenomenon here, requiring each person to know at least the native language of that person's group.

ASSUMPTION 4

Each language has a *difficulty* for each group. The difficulty of each group's native language for the group is 0. The difficulty of the artificial language is positive, is equal for each group, and is less than the difficulty of either group's

foreign language for the group.

Motivation. By most accounts, natural languages differ substantially in the difficulty they present to nonnative learners. The variability of the difficulty of foreign languages is all the more understandable if we use "difficulty" as a summary for various group-specific obstacles to learning, including not only time and money but also attitudinal barriers arising from group hostility and feelings of superiority and inferiority. By contrast, while an artificial language can be more similar to one group's native language than to another and thereby easier for one group than for another group to learn, this effect appears to be minor; instead, regularity is the overwhelming determinant of learning effort (Lenneberg 1957). On this basis, I ignore here the possibility that the artificial language is more difficult for one group than for the other. Since learning-speed experiments have typically shown an artificial language to require only about one-fifth the learning time of a natural language, I also assume that this difference is never reversed. The relative difficulties of languages may differ among individuals with the same native language, but it is reasonable to assume that such differences are minor compared with differences between native-language groups, so I ignore the within-group differences here to simplify the analysis.

ASSUMPTION 5

Each person has a positive *language aptitude*. Each person's language aptitude differs from that of each other person in the same group. The persons in each group are ordered according to increasing language aptitudes.

Motivation. I assume that a person's language aptitude is generic to all languages, natural and artificial. For analytic simplicity, I force all persons in a group to have (at least infinitesimally) different language aptitudes.

ASSUMPTION 6

Each person has a *language cost* equal to the sum of the difficulties for the person's group of the languages in the person's language repertoire, divided by the person's language aptitude.

Motivation. I assume here that to learn languages i and j requires the effort of learning i plus the effort of learning j. I thus neglect possible economies of scale. Learning a nonnative language, especially an artificial language, may facilitate learning a different language later (Pool 1981, 158–59), but the

evidence for this effect is still meager.

ASSUMPTION 7

Each person has a *language reach* equal to the proportion of the population whose language repertoires share at least one language with the person's language repertoire.

Motivation. I assume that any two persons who know at least one common language can communicate, and the number of persons with whom one can communicate is one's language reach. I thereby ignore any advantage obtained from one's native language being the medium of communication (an advantage considered by Colomer 1990), from the ability to overhear communications that take place between other persons, and from communication via translators.

ASSUMPTION 8

Each person has a *language benefit* equal to some increasing function, identical for all persons, of the person's language reach.

Motivation. I am assuming here that benefits may fail to be proportional to language reach. For example, the marginal benefit from additional units of language reach may decline as language reach increases. Whatever the function is, I assume it is the same for all persons and that a person always prefers more language reach to less. The assumed invariance of the benefit function does not impute identical welfare functions to all persons, as seen in the next assumption.

ASSUMPTION 9

Each person has a *language welfare* equal to the person's language benefit reduced by the person's language cost.

Motivation. Of the two assumed components of language welfare, language cost depends partly on language aptitude, which varies among persons. I use language aptitude to represent all within-group differences in language-learning motivations. Thus, persons who would be called easy language learners and persons who would be called intense enjoyers of communication in ordinary life are both called persons with high language aptitude in the model. This simplification is innocuous because I make no use of interpersonal welfare differences; I compare only the welfare differences for a person arising

from the person's alternative language repertoires.

ASSUMPTION 10

An *outcome* is a mapping of the persons in each group to the set of the group's language alternatives.

Motivation. Every possible way in which the persons in the world can be allocated among their possible language repertoires is a different outcome. Situations that differ not in *how many* persons have each language repertoire but only in *which* persons have each language repertoire constitute different outcomes. The reason is that persons might plausibly behave differently in these different situations.

ASSUMPTION 11

A *best reply* of a person to an outcome is a language repertoire that would maximize the person's language welfare if the language repertoires of all other persons remained unchanged.

Motivation. I am ignoring the possibility that persons might coordinate their responses to an outcome. Each person is presumed to determine which language repertoire(s) would maximize the person's language welfare. In making this determination, the person is presumed to ignore the possibility that other persons might also change their language repertoires.

ASSUMPTION 12

If some outcome *j* can be derived from some outcome *i* by each person adopting some best reply to outcome *i*, then outcome *j* is a *successor* to and a *consequence* of outcome *i*. A successor to a consequence of an outcome is also a consequence of the outcome.

Motivation. I envision all persons examining the outcome and simultaneously making any adjustments to their language repertoires that would maximize their own language welfares if all other persons' language repertoires were to remain unchanged. Since adjustments by several persons could render each other suboptimal, sets of adjustments might take place repeatedly. As they did, each outcome would be a "successor" to the previous outcome and a "consequence" of all prior outcomes in the chain.

ASSUMPTION 13

An outcome which is a successor to itself is *stable*.

Motivation. Here, I define a stable outcome as a Nash equilibrium, namely, as a situation in which no person can obtain a language welfare increase by changing single-handedly to a different language repertoire when all other persons retain their current language repertoires.

ASSUMPTION 14

A *utopia* is an outcome in which every person's language repertoire includes the artificial language. A *take-off point* is an outcome other than a utopia at least one of whose consequences is a stable utopia.

Motivation. We are interested in whether there is some outcome in which not every person knows the artificial language, but which could initiate a chain of adjustments leading to an outcome in which everyone knows the artificial language and no one has an incentive to change language repertoires. This assumption defines such an initial point.

RESULTS, PROOFS, AND DISCUSSION

Under the foregoing model, is there a take-off point? Is there some subset of the population whose knowledge of the artificial language would induce each remaining member of the population to learn the language? And if this happened, would the resulting situation be stable? I shall present six results, followed by proofs and discussions.

RESULT 1

No stable outcome exists in which any person's language repertoire includes both the artificial language and the foreign language.

Proof. Suppose some person's language repertoire includes both the artificial language and the foreign language. That person's language welfare is less than it would be if the artificial language were deleted from the language repertoire. Deleting the artificial language would reduce the person's language cost (by Assumption 6) but not change the person's language benefit (because by Assumption 7, the person's language reach would remain at 1). Therefore, the

deletion would increase the person's language welfare, implying that the outcome is not stable.

Discussion. Given Result 1, there are only three language repertoires that might occur in any stable outcome: (a) native language, (b) native language and artificial language, and (c) native language and foreign language. This result would become more complex, however, if we relaxed Assumption 1 to permit more than two groups.

RESULT 2

In every stable outcome, the persons in each group with each language repertoire constitute one compact set, and the sets in each group are ordered as follows: (a) native language, (b) native language and artificial language, and (c) native language and foreign language.

Proof. I arbitrarily number the Groups 1 and 2 and number each group's native language with the number of the group. I then define the following terms:

s_i	=	group i as a fraction of the population
d_i	=	the difficulty of foreign language i for the group not having i as its native language
d_a	=	the difficulty of the artificial language
n	=	a language repertoire including only the native language
a	=	a language repertoire including only the native language and the artificial language
f	=	a language repertoire including only the native language and the foreign language
l_i	=	persons in group i whose language repertoire is l, as a fraction of the population
r_{il}	=	the language reach of each person in group i whose language repertoire is l
$b(r)$	=	the language benefit of each person with language reach r
$c_{il}(q)$	=	the language cost of a person in group i whose language repertoire is l

and whose language aptitude is q

$w_{il}(q)$ = the language welfare of a person in group i whose language repertoire is l and whose language aptitude is q

Suppose that in some stable outcome, some person in group i (the other group being j) has language aptitude q and language repertoire n. By Assumption 9, that person's language welfare is

$$w_{in}(q) = b(r_{in}) = b(s_i + f_j). \tag{1}$$

The person's other possible language repertoires would have produced these language welfares:

$$w_{ia}(q) = b(r_{ia}) - c_{ia}(q) = b(s_i + f_j + a_j) - \frac{d_a}{q}; \tag{2}$$

$$w_{if}(q) = b(r_{if}) - c_{if}(q) = b(1) - \frac{d_j}{q}. \tag{3}$$

Because the outcome is stable, the person's actual language welfare must be at least what either of its alternatives would be:

$$w_{in}(q) \geq w_{ia}(q); \tag{4}$$

$$w_{in}(q) \geq w_{if}(q). \tag{5}$$

Now, consider some other person in the same group, having language aptitude p, with $p < q$. Suppose this person had language repertoire a. That would imply, in a stable outcome, that

$$w_{ia}(p) \geq w_{in}(p), \tag{6}$$

which in turn would imply that

$$b(s_i + f_j + a_j) - \frac{d_a}{p} \geq b(s_i + f_j). \tag{7}$$

But the fact that $p < q$ implies that

$$b(s_i + f_j + a_j) - \frac{d_a}{p} < b(s_i + f_j + a_j) - \frac{d_a}{q} = w_{ia}(q) \leq w_{in}(q) = b(s_i + f_j), \tag{8}$$

contradicting Inequality 7. Thus, the person with language aptitude p cannot have language repertoire a.

A parallel argument applies to language repertoires n and f. Suppose the person with language aptitude p ($p < q$) had language repertoire f. Stability would imply that

$$w_{if}(p) \geq w_{in}(p), \tag{9}$$

which in turn would imply that

$$b(1) - \frac{d_j}{p} \geq b(s_i + f_j). \tag{10}$$

But the fact that $p < q$ implies that

$$b(1) - \frac{d_j}{p} < b(1) - \frac{d_j}{q} = w_{if}(q) \leq w_{in}(q) = b(s_i + f_j), \tag{11}$$

contradicting Inequality 10. Thus, the person with language aptitude p cannot have language repertoire f.

A final parallel argument applies to language repertoires a and f. Suppose the person with language aptitude q has language repertoire a. Then

$$w_{ia}(q) \geq w_{in}(q); \tag{12}$$

$$w_{ia}(q) \geq w_{if}(q). \tag{13}$$

And suppose the person with language aptitude p ($p < q$) had language repertoire f. Stability would imply that

$$w_{if}(p) \geq w_{ia}(p), \tag{14}$$

from which we could derive:

$$b(1) - \frac{d_j}{p} \geq b(s_i + f_j + a_j) - \frac{d_a}{p}; \tag{15}$$

$$b(1) \geq b(s_i + f_j + a_j) + \frac{d_j - d_a}{p}. \tag{16}$$

But the facts that $p < q$ and $d_a < d_j$ imply that

$$b(s_i + f_j + a_j) + \frac{d_j - d_a}{p} > b(s_i + f_j + a_j) + \frac{d_j - d_a}{q} = w_{ia}(q) + \frac{d_j}{q} \tag{17}$$

$$\geq w_{if}(q) + \frac{d_j}{q} = b(1) - \frac{d_j}{q} + \frac{d_j}{q} = b(1),$$

contradicting Inequality 16. Thus, the person with language aptitude p cannot have language repertoire f.

I have shown that, in any stable outcome, in each group (a) every person with language repertoire a must have a greater language aptitude than any person with language repertoire n, (b) every person with language repertoire f must have a greater language aptitude than any person with language repertoire n, and (c) every person with language repertoire f must have a greater language aptitude than any person with language repertoire a. These requirements, together with Assumption 5, which orders each group's persons according to increasing language aptitude, imply Result 2.

Discussion. Under Assumptions 1 and 5, each group is a continuum of persons, ordered from least to greatest language aptitude. I have shown that in a stable outcome the 3 language repertoires that might occur among the persons in a group are compact with respect to language aptitude. There are two *boundaries* in each group. Below the first boundary, all persons know only the native language. Between the boundaries, they know only the native and the artificial languages. Above the second boundary, they know only the native and the foreign languages. This result also follows directly from Theorem 1 in Selten and Pool (1991). I shall call any outcome that exhibits the compactness and order described by Result 2 a *regular* outcome. Figure 1 gives an example of what the distribution of language aptitudes and language repertoires in a group might look like in a regular outcome.

Result 2 becomes plausible when we consider the components of a person's language welfare (Equations 1 through 3). The benefit term in each person's language welfare does not depend on the person's language aptitude. All persons in the same group having the same language repertoire get the same language benefit. But the cost term does depend on the person's language aptitude. As we move from language repertoire n (knowing only the native language) to language repertoire a (knowing the native and artificial languages) to language repertoire f (knowing the native and foreign languages), the difficulty increases, and therefore the effect of the person's language aptitude also increases. With language repertoire n, the difficulty is 0, so language aptitude has no effect. With language repertoire f, the difficulty is the greatest, so language aptitude has the greatest effect. Thus, it is plausible that, if a person finds the cost of moving to a more costly language repertoire greater than the benefit that would be derived from doing so, another person with less language aptitude—who would have to pay an even greater cost—will find the same move even less worth making. It is thus not surprising that the three language repertoires, in a stable outcome, cannot alternate, but must be located

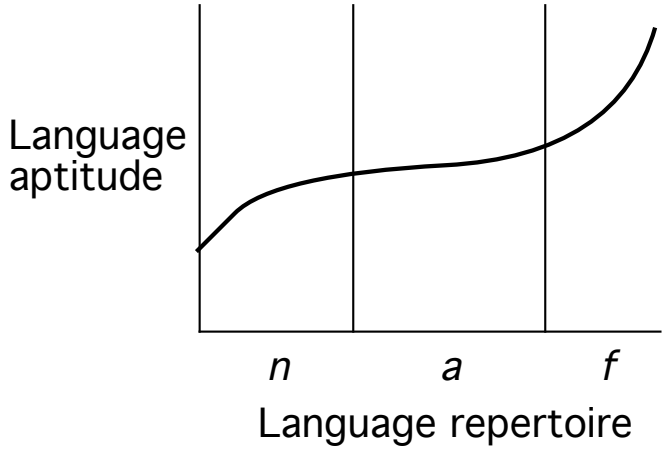

Figure 1: Distribution of a hypothetical group's language aptitudes and language repertoires in a regular outcome.

Note: *n* = knows only native language; *a* = knows native and artificial language; *f* = knows native and foreign language.

in three separate uninterrupted regions of language aptitude in each group.

In a regular outcome a group might exhibit one or two instead of all three possible language repertoires. In such cases, one or both boundaries will be located at the beginning or end of the group, and/or the two boundaries will coincide.

If the distributions of language repertoires of both groups in a regular outcome are plotted against each other, we can obtain a graphical representation of the language reach that each person in the population enjoys. Figure 2 gives an example for two hypothetical groups. Each person's language reach includes the person's entire own group and one, two, or all three of the language-repertoire regions of the other group.

RESULT 3

A utopia is stable under some but not all conditions.

Proof. Suppose that the language aptitude q of every person in each group i

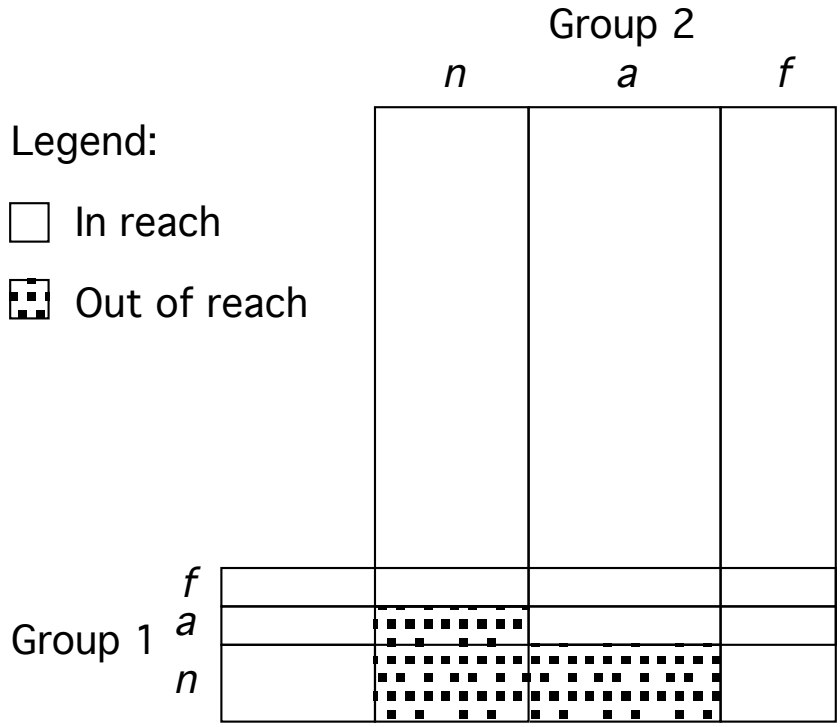

Figure 2.: Distribution of language reaches in a hypothetical regular outcome

satisfies the inequality

$$q \geq \frac{d_a}{b(1) - b(s_i)}. \tag{18}$$

Let a *minimal utopia* be the outcome in which every person's language repertoire is a. In this case, $f_1 = f_2 = 0$ (because no person knows a foreign language), and $a_1 = s_1$ and $a_2 = s_2$ (because every person knows the artificial language). In choosing a reply to the minimal utopia, each person chooses among the 3 possible language welfares given by Equations 1 through 3, which in this case become

$$w_{in}(q) = b(s_i + f_j) = b(s_i); \tag{19}$$

$$w_{ia}(q) = b(s_i + f_j + a_j) - \frac{d_a}{q} = b(s_i + s_j) - \frac{d_a}{q} = b(1) - \frac{d_a}{q}; \tag{20}$$

$$w_{if}(q) = b(1) - \frac{d_j}{q}. \tag{21}$$

Of these quantities, $w_{ia}(q)$ is maximal for every person, as shown by

$$w_{ia}(q) = b(1) - \frac{d_a}{q} \geq b(1) - \frac{d_a}{\dfrac{d_a}{b(1) - b(s_i)}} = b(s_i) = w_{in}(q) \tag{22}$$

and

$$w_{ia}(q) = b(1) - \frac{d_a}{q} > b(1) - \frac{d_j}{q} = w_{if}(q). \tag{23}$$

It follows that the existing language repertoire is a best reply for every person, and the minimal utopia is stable.

Conversely, now suppose that there is at least one person for whom Inequality 18 is false. For each such person, Inequality 22 is false and hence the existing language repertoire a is not a best reply. Under this condition, therefore, the minimal utopia is not stable. But no utopia other than the minimal utopia is stable either, because such stability would violate Result 1. Hence, when Inequality 18 is false no utopia is stable.

Discussion. When every person knows the artificial language and no person knows a foreign language, we have a "minimal utopia." It is the only kind of utopia that might be stable, because any other utopia has at least one trilingual, and Result 1 says no such outcome is stable. But even a minimal utopia is not always stable. It is stable when, and only when, no person can obtain a welfare increase by either returning to monolingualism or replacing the artificial language with the foreign language. The latter change can never be profitable in the minimal utopia, because it would increase a person's language cost without changing the person's (already total) language reach. But abandoning the artificial language is profitable if the reduction in language cost is greater than the reduction in language benefit (or, equivalently, if Inequality 18 is false). Thus, a minimal utopia is always stable against defections to the foreign language, but not always against defections to monolingualism.

RESULT 4

A take-off point exists under some but not all conditions.

Proof. Result 3 says that a stable utopia does not necessarily exist. A take-off point by definition (see Assumption 14) has a stable utopia as a consequence. Therefore, whenever such an outcome does not exist a take-off point also does not exist.

We can, however, define conditions under which a take-off point exists. Let Inequality 18 for every person be strongly satisfied, namely with ">" in place of "≥". Then, by Result 3, the minimal utopia is stable. Change the minimal utopia by changing one arbitrary person's language repertoire from a to n. The new outcome, like the original outcome, offers all persons the three possible language welfares given in Equations 19 through 21, because the removal of one person from a_i does not change the magnitude of $a_{\dot{i}}$. So, a is a best reply for every person. In other words, the minimal utopia is not only stable but also a successor to a different outcome. That different outcome is therefore a take-off point.

Discussion. A take-off point may or may not exist. At least one take-off point exists whenever native-artificial bilingualism is uniquely welfare-maximizing for at least one person in a world where all persons in the other group are native-artificial bilinguals. This condition, in turn, is met whenever (a) at least one person has a sufficiently high language aptitude, (b) the difficulty of the artificial language is sufficiently small, and (c) the increased language benefit that comes from having everyone in one's language reach, instead of having only one's own group, is sufficiently great.

In addition to utopias, namely outcomes in which everyone knows the artificial language, other outcomes might be stable, and in some of these outcomes some but not all persons might know the artificial language. I shall conclude with two results about the stability of outcomes more generally.

RESULT 5

No stable outcome exists in which the language repertoire of (a) any of one group and none of the other group includes the artificial language, (b) all of one group includes the artificial language and any of the other group includes the foreign language, or (c) all of one group and any of the other group includes the foreign language.

Proof. Result 5 can be summarized with the following three inherently

unstable conditions, where ∃ indicates that the set of persons in the given group with the given language repertoire is not empty, although it may have magnitude 0, representing an infinitesimal subset of the group:

$$\exists\, a_i \text{ and } a_j = 0; \qquad \text{(Condition 1)}$$

$$a_i = s_i \text{ and } \exists\, f_j; \qquad \text{(Condition 2)}$$

$$f_i = s_i \text{ and } \exists\, f_j. \qquad \text{(Condition 3)}$$

In an outcome meeting Condition 1, each person in group i with a language repertoire that includes the artificial language can obtain a welfare increase by abandoning the artificial language, because it contributes nothing to the person's language reach. In an outcome meeting Condition 2, each person in group j with a language repertoire that includes the foreign language can obtain a welfare increase by replacing it with the artificial language, because this will reduce the person's language cost but not the person's language reach. In an outcome meeting Condition 3, each person in group j with a language repertoire that includes the foreign language can obtain a welfare increase by abandoning the foreign language, because this will reduce the person's language cost but not the person's language reach. Therefore, no outcome meeting any of these conditions is stable.

Discussion. In any stable outcome there are three possible language repertoires that can exist in any group, according to Result 1. Since each group must exhibit at least one of the possible language repertoires, there are seven sets of language repertoires that any group might exhibit in a stable outcome. The possible sets of language repertoires can therefore form 28 different pairs. But of the 28 pairs 15 are excluded as inherently unstable by Result 5. Table 1 shows the 28 pairs and classifies each as possibly stable or inherently unstable.

The most general class of outcomes shown in Table 1 is outcomes in which both groups exhibit all three possible language repertoires, namely, the class shown in the upper-left cell. All the other classes can be interpreted as degenerate cases of this class. I shall now define a subclass consisting of all outcomes in this class (a) which are regular and (b) in which n_i, a_i, and f_i are all positive for each group i, in other words in which all the possible language repertoires of a regular outcome are represented by more than infinitesimal fractions of each group. Any outcome in this subclass is an *internal* outcome.

Table 1. Possibly Stable and Inherently Unstable Classes of Outcomes

Group *i*							
naf	*na*	*nf*	*af*	*n*	*a*	*f*	
+[a]	+	0	+	0	0	0	*naf*
	+	0	+	0	+	0	*na*
		+	0	+	0	0	*nf*
			+	0	0	0	*af*
				+	0	+	*n*
					+[b]	0	*a*
						0	*f*

Group *j*

NOTE: Row and column headings show the language repertoires of nonempty subsets of the group. A plus sign (+) = outcomes with this pair of sets of language repertoires may be stable; 0 = outcomes with this pair of sets of language repertoires cannot be stable.

a. Internal outcomes belong to this class.

b. All outcomes in this class are utopias.

RESULT 6

Every internal outcome is stable for some language benefit function and some set of language aptitudes.

Proof. Consider (a) a situation described by the difficulties d_i, d_j, and d_a and the group sizes (as fractions of the population) s_i and s_j; (b) an internal outcome described by n_i, a_i, n_j, and a_j (f_i and f_j being determined by these); and (c) a language benefit function satisfying the constraint

$$b(1-n_i) > \left(1-\frac{d_a}{d_i}\right) b(1-n_i-a_i) + \frac{d_a}{d_i} b(1) \tag{24}$$

for each group *i*. This constraint complies with Assumption 8's requirement that language benefit be an increasing function of language reach. The inequality describes the benefits of three language reaches. The benefit of the intermediate language reach, on the left side, is constrained to be greater than a weighted mixture of the benefits of the largest and smallest language reaches,

on the right side. Thus, the left-hand benefit is constrained to be greater than the benefit of the smallest language reach, and it is allowed to be less than the benefit of the largest language reach, $b(1)$.

This constraint can always be simultaneously satisfied for Groups 1 and 2. Whichever group's right-hand side is the greater, the range of values between that quantity and $b(1)$ is allowed to both groups' left-hand sides. Values within that range can be assigned to the left-hand sides in compliance with Assumption 8, depending on the relative magnitudes of n_1 and n_2.

Having shown that a language benefit function satisfying Inequality 24 for both groups always exists, I shall show that under any such language benefit function there is a set of language aptitudes that makes the outcome stable. Again representing each group i as a continuum with end points 0 and s_i, and each person in group i as a point on the continuum, I shall describe the language aptitude of the person at point x in group i with the term $q_i(x)$. We shall then see that there is a language aptitude distribution satisfying the constraints

$$q_i(n_i) = \frac{d_a}{b(1-n_j) - b(1-n_j-a_j)} \tag{25}$$

and

$$q_i(n_i + a_i) = \frac{d_j - d_a}{b(1) - b(1-n_j)}, \tag{26}$$

both for $i = 1$ and $j = 2$ and for $i = 2$ and $j = 1$, and making the outcome stable.

A language aptitude distribution satisfying Equations 25 and 26 *exists* because when the language benefit function satisfies Inequality 24 it is possible to satisfy Equations 25 and 26 without violating Assumption 5. We can show this as follows:

$$q_j(n_j) = \frac{d_a}{b(1-n_i) - b(1-n_i-a_i)} = \frac{\left(1-\frac{d_a}{d_i}\right)d_a}{\left(1-\frac{d_a}{d_i}\right)b(1-n_i) - \left(1-\frac{d_a}{d_i}\right)b(1-n_i-a_i)} \tag{27}$$

$$< \frac{\left(1-\frac{d_a}{d_i}\right)d_a}{\left(1-\frac{d_a}{d_i}\right)b(1-n_i) - \left(b(1-n_i) - \frac{d_a}{d_i}b(1)\right)} = \frac{\left(\frac{d_i-d_a}{d_i}\right)d_a}{-\frac{d_a}{d_i}b(1-n_i) + \frac{d_a}{d_i}b(1)}$$

$$= \frac{d_i - d_a}{b(1) - b(1-n_i)} = q_j(n_j + a_j).$$

A language aptitude distribution satisfying Equations 25 and 26 *makes the outcome stable* because it makes each person's language repertoire a best reply for that person to the outcome. We can show this, for each group i, by comparing each person's language welfare with the other two language welfares available to the person. We must do this separately for the persons who have each language repertoire, making six comparisons. For those with language repertoire n:

$$w_{in}(q) = b(s_i + f_j) = b(1 - n_i - a_j) = b(1 - n_i) - b(1 - n_j) + b(1 - n_j - a_j) \tag{28}$$

$$= b(1 - n_i) - \frac{d_a}{\frac{d_a}{b(1 - n_i) - b(1 - n_j - a_j)}} = b(1 - n_i) - \frac{d_a}{q_i(n_i)}$$

$$\geq b(1 - n_i) - \frac{d_a}{q} = b(s_i + f_j + a_j) - \frac{d_a}{q} = w_{ia}(q);$$

$$w_{in}(q) \geq b(1 - n_j) - \frac{d_a}{q} = b(1 - n_j) + \frac{d_j}{q} - \frac{d_a}{q} - \frac{d_j}{q} = b(1 - n_j) + \frac{d_j - d_a}{q} - \frac{d_j}{q} \tag{29}$$

$$> b(1 - n_j) + \frac{d_j - d_a}{q_i(n_i + a_i)} - \frac{d_j}{q} = b(1 - n_j) + \frac{d_j - d_a}{\frac{d_j - d_a}{b(1) - b(1 - n_j)}} - \frac{d_j}{q}$$

$$= b(1) - \frac{d_j}{q} = w_{if}(q).$$

For those with language repertoire a:

$$w_{ia}(q) = b(1 - n_j) - \frac{d_a}{q} \geq b(1 - n_j) - \frac{d_a}{q_i(n_i)} = w_{in}(q); \tag{30}$$

$$w_{ia}(q) \geq b(1 - n_j) - \frac{d_a}{q_i(n_i)} = b(1 - n_j - a_j) > \frac{\frac{d_a}{d_j}b(1) - b(1 - n_j)}{\frac{d_a}{d_j} - 1} \tag{31}$$

$$= \frac{\frac{d_a}{d_j}b(1) - b(1) + b(1) - b(1 - n_j)}{\frac{d_a}{d_j} - 1} = b(1) + \frac{b(1) - b(1 - n_j)}{\frac{d_a - d_j}{d_j}}$$

$$= b(1) - d_j\frac{b(1) - b(1 - n_j)}{d_j - d_a} = b(1) - \frac{d_j}{\frac{d_j - d_a}{b(1) - b(1 - n_j)}} = b(1) - \frac{d_j}{q_i(n_i + a_i)}$$

$$\geq b(1) - \frac{d_j}{q} = w_{if}(q).$$

And for those with language repertoire *f*:

$$w_{if}(q) = b(1 - n_j) + \frac{d_j - d_a}{q_i(n_i + a_i)} - \frac{d_j}{q} \geq b(1 - n_j) + \frac{d_j - d_a}{q} - \frac{d_j}{q} = b(1 - n_j) - \frac{d_a}{q} \tag{32}$$

$$> b(1 - n_j) - \frac{d_a}{q_i(n_i)} = w_{in}(q);$$

$$w_{if}(q) \geq b(1 - n_j) - \frac{d_a}{q} = w_{ia}(q). \tag{33}$$

Discussion. I have shown that every internal outcome—every outcome in which monolinguals, native-artificial bilinguals, and native-foreign bilinguals all constitute positive fractions of both groups—can be stable. Its stability imposes certain requirements on the language benefit function and on the distributions of language aptitudes. But these requirements are never impossible to meet.

CONCLUSION

It is widely assumed that the worldwide adoption of an artificial language for international communication is feasible if a large enough number of persons learn such a language, and that some number of speakers constitutes a take-off point. When fewer than that number know the language, it is believed to be likely to die out. When more than that number know it, it is believed to be destined to continue acquiring more speakers, until it becomes universally known. The idea that drives these beliefs is that a language's value to its speakers varies directly with the number of others who also speak it.

I have challenged this picture of the problem by constructing a model that incorporates the realistic assumption that those who know an artificial language when it is not universally known are not necessarily a cross-section of the world population. In my model, persons may choose to learn no language, to learn the artificial language, to learn a foreign language, or to learn both the artificial language and a foreign language. They adopt whichever of these language repertoires maximizes their language welfare, which depends partly on their language-learning propensities.

Under this assumption, universal competence in an artificial language may be stable and may be reachable from some other take-off point, as is commonly assumed, but may instead be unstable. Furthermore, knowledge of the artificial language by a small fraction of the world population—no matter how small—need not spell the death of the language. Such an outcome can be stable. What would necessarily be unstable would be the presence of its speakers—no matter how many—in a single language group. So confined, they would derive no communicational benefit from their knowledge of the language.

Although the model explored here is a model of a 2-group world, and the robustness of its results will depend on whether they persist for more complex models of multigroup worlds, the above results may still give some insights into important features of the fate of proposed artificial world languages.

INSIGHT 1

For almost a century Esperanto has been the prevailing artificial language in competition for the role of world language, and its number of speakers has been remarkably stable. During this same time the number of persons learning French as a nonnative language has plummeted, while the number learning English has multiplied. A possible interpretation of this contrast is that natural and artificial languages constitute distinct language markets. English and French compete with one another (and with other natural languages), but neither competes much with Esperanto. The reason suggested by this model is that the two kinds of languages appeal to persons in different ranges of language-learning propensity. Esperanto is, in this light, not a pastime for polyglots, but a blessing for the linguistically isolated. This view clashes with an outsider stereotype, but not with what experienced observers know about the Esperantist rank and file (Forster 1982, 319; Piron 1989, 171).

INSIGHT 2

Given the small fraction of the world population knowing an artificial language, its promoters are aware of the danger that this fraction will become still smaller because the cost of learning it (even if only a fraction of the cost of learning a natural language) is greater than the benefits available to its speakers. In this light, it is understandable that the promoters of Esperanto invest resources in making its few speakers accessible to one another. The speakers of Esperanto are organized into world, national, and special-interest associations (e.g., the blind, chess players, railroad workers). In addition,

thousands of speakers register as consultants and promise to respond to recreational, commercial, and professional inquiries from other speakers. This practice appears to have the effect of multiplying the extent to which each speaker adds to each foreign speaker's "language reach."

INSIGHT 3

The most successful artificial languages have had speakers who considered themselves members of missionary movements. However, the prevailing mood in these movements has been disappointment at the small numbers of recruits. One interpretation of this failure is that targets of recruitment provide inversely associated difficulties and incentives. For an existing speaker, the easiest-to-reach targets are persons within the same native-language group (for both linguistic and geographical reasons). But it is precisely these targets who offer an existing speaker the least incentive to invest in recruitment. By recruiting one of them, the recruiter experiences no increase whatever in language reach. It is foreign recruits who benefit an existing speaker the most, but whose numbers an existing speaker has the least opportunity to influence.

INSIGHT 4

Myopic and farsighted expectations about changing distributions of language repertoires can be substantially different. Myopic expectations are based on the best replies of all persons to the status quo. Farsighted expectations are based on the same best replies, on the best replies of all persons to the outcome that will be produced by the initial set of best replies, and so on. Persons promoting a language have sometimes been complacent when they perceived that only a small fraction of the language's current speakers was rationally motivated to defect from the language. But they apparently failed to contemplate that the new outcome that would emerge from the initial defections would motivate additional defections and that this process would continue until the language disappeared from use (Schiffman 1987). My model permits this stepwise evolution of a distribution of language repertoires, suggesting that complacency may also affect the behavior of those who promote world languages. As an example, I present in Figure 3 a simulation of the disappearance of an artificial language which at the beginning of the simulation is known by the entire population of the world. The figure shows an adaptation at Time 1 by those with the lowest language aptitudes, who defect to monolingualism. Their defection motivates two subsequent counter-adaptations. (a) Those (in the other group) with the highest language aptitudes switch from the artificial language to their foreign language. (b) More of those

(also in the other group) with the lowest language aptitudes switch from the artificial language to monolingualism. These counter-adaptations motivate the same kinds of counter-adaptations from the original group at Time 3, and so on. Eventually, there are monolinguals and bilinguals in both groups, but all the bilinguals are native-foreign bilinguals.

INSIGHT 5

When persons choose whether to learn a nonnative language, they affect the welfare of other persons as well as their own welfare. It is therefore no surprise that governments often coerce persons to learn (or not learn) languages and that such coercion often receives some public approval. Under the assumptions of my model, persons who choose not to learn the artificial language thereby maximize (myopically) their own language welfares. But they also, as a side-effect, may reduce the language welfares of others by reducing their language reaches. When these externalities are taken into account, the equilibrium that emerges from an initial utopia with freedom of individual choice may be interpretable as a socially deficient outcome.

An illustration of such a result is given in Figure 4. In this example, no one ever learns a foreign language, but the utopia breaks down as the lowest-aptitude persons in each group choose monolingualism. In the end, some of these persons experience a welfare gain, but others experience a loss, as do all those who remain bilingual. Were units of welfare interpersonally commensurable, in this example the losers could have easily compensated the gainers and retained a surplus by inducing retention of universal native-artificial bilingualism.

The fact that the model can produce such examples may give insight into the normative plausibility of demands to regulate individuals' choices of language repertoires. In the case of artificial languages, promoters portray their problem as a coordination problem not only because they believe (perhaps incorrectly) that they will achieve lasting victory once they recruit enough speakers to surpass a take-off point. They also often voice the belief, less easily rebutted, that choices of language repertoires need to be contractually or politically coordinated in order to maximize social welfare.

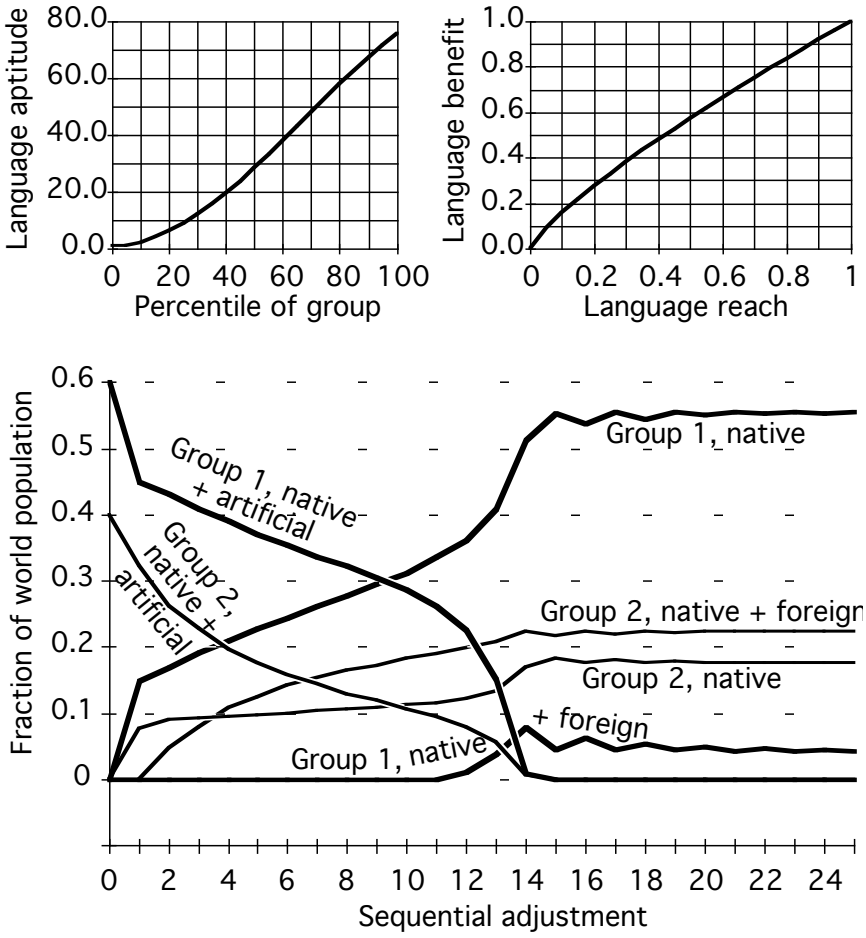

Figure 3: Evolution of language repertoires in a hypothetical world from a utopian status quo

NOTE: In the assumed situation, Group 1 has 60% and Group 2 has 40% of the world population. The difficulties of Group 1's language, Group 2's language, and the artificial language are 11, 10, and 3, respectively. The groups' language aptitude distributions—$q_i(x) = -70(x/s_i)^3 + 145(x/s_i)^2 + 1$—graphed above, are identical. The language benefit function ($b = r^{0.8}$) is also graphed above. At the beginning (Time 0), all persons are native-artificial bilinguals.

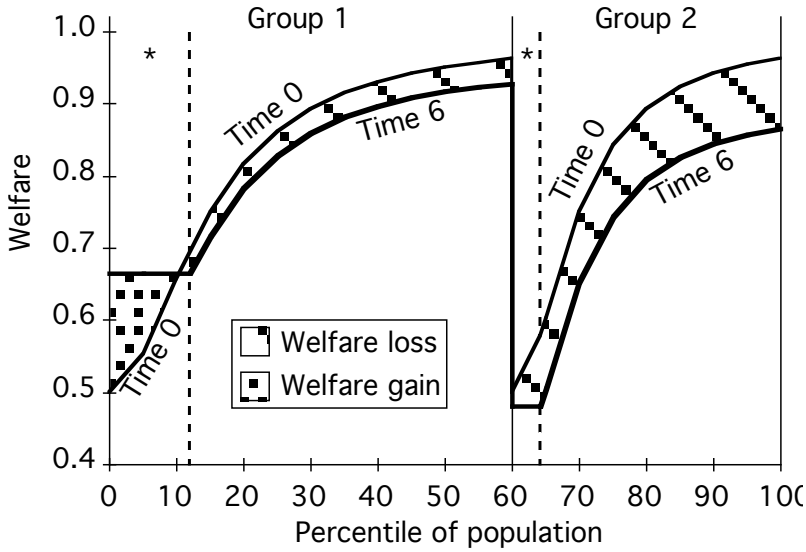

Figure 4: Effect on language welfare of hypothetical evolution of language repertoires from a utopian status quo

NOTE: The assumed situation is identical to that of Figure 3 except that the groups' language aptitude distribution is $q_i(x) = -29(x/s_i)^3 + 103(x/s_i)^2 + 6$. An approximate equilibrium is reached in 6 adjustments, with persons in regions marked with an asterisk (*) being monolingual and all others remaining native-artificial bilinguals.

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