Toward a Sociogenetic Solution:

Examining Language Formation Processes Through SWARM Modeling

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Creole languages are often a point of contention for theoretical linguistics. Broadly defined, creoles result from an amalgamation of two or more languages, when speakers of differing mother tongues need rudimentary communication during economic or social transactions. Creolization occurs if the "invented" system becomes the native language of the speech community. There are several hypotheses for how biological linguistic properties and social contact each bear on the formation of creoles; however, until recently, no reliable method for testing these complex interactions existed. Implementing SWARM 2.1.1, the current model consists of a multiagent population drawn from historical records of Surinamese sugar cane plantations. Each agent in this artificial society is endowed with a demographic profile and linguistic parameters. Three experiments using the SWARM model are described. The results provide viable motivation for advancing a "sociogenetic" solution for the emergence of prototypical creole languages.

Keywords: language contact, pidgins and creoles, language acquisition

This article simulates a language formation process known as creolization, using a computer program that tracks "speaker-agents" who enter and emerge from a language learning environment. Throughout history, creole languages have been documented only in restricted social contexts, during trade transactions, or under circumstances of upheaval such as slavery. In such cases, speakers of diverse languages are able to bridge a communication gap even when there is little opportunity or will to learn others' language(s). The situation results in the use of a simplified communication system known as a *pidgin*.[1] In time, this newly formed code may nativize (become the native tongue in a speech community), at which point we say that the pidgin has *creolized*. The resultant language is called a *creole* (Arends, Muysken, & Smith, 1994; Sebba, 1998).

Where the controversy lies, and where motivation for agent-based modeling begins, is that unlike pidgins that confine themselves to a few simple structures, the creole language regularizes and expands into complex structures of grammar and inflectional forms. These innovations are akin to what is observed in "normally" transmitted native languages, despite the fact that the pidgin elements that purportedly function as the creole's primary linguistic input are highly deficient. Moreover, some researchers argue that creoles worldwide maintain a striking uniformity in linguistic typology, such that among themselves they share far-reaching similarities with respect to word order, classes of morphological markers used, word compounding strategies, and so forth. In turn, these common features are said to make

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creolized languages distinguishable from "conventionally" acquired languages (Bickerton, 1999).

Because pidgins are conceived as second languages and never constitute a mother tongue for any speaker, the inevitable question raised is how a full and nativized creole language is acquired given the unstable and "degenerate" linguistic environment from which it originates. Most researchers would agree that the obvious reply must look to both nature (biological capacity for humans to acquire language) and nurture (external features shaping human development) for the ultimate solution. However, this illusory consensus is not actively integrated into standard research paradigms, for reasons that may have more to do with limitations in empirical and/or conceptual scope. In effect, a large number of investigations concerning creole formation continue to fixate on the task of proving the strong preponderance of the social (external) component of language acquisition over the genetic (internal) aspect or vice versa. Below, I sketch in greater detail the divide that has held between these two hypotheses.

Current theoretical formulations such as the Principles and Parameters framework (Chomsky, 1981, 1986, and subsequent versions) have begun to fruitfully approach the puzzle of how children from widely differing backgrounds universally converge on an appropriate target grammar with relative rapidity and ease. These studies characterize the human capacity for language as a genetic endowment, the core of which stems from universal grammar (UG), the biological faculty for language acquisition. To this end, Bickerton (1984, 1992) advanced the *language bioprogram hypothesis* (LBH) as a universalist proposal that outlines the nature of UG properties given various populations of first-language learners. At its most extreme, the LBH depicts the uniformity of creolization as the result of a nonarbitrary, "bet-hedging" reflex connected solely to biological (first) language acquisition processes. Given a chaotic linguistic environment, innate blueprints are argued to automatically yield the most generic, or unmarked, structures possible for natural language, such as those forms reportedly found across creole languages. To the extent that children exclusively have full access to UG and are thus capable of creating a complete creole (as a mother tongue emerging in language contact situations), there is also a basis for the related claim that creole languages emerge abruptly within one generation of (child) speakers (Bickerton, 1988).

The contrasting viewpoint can be labeled the *social context hypothesis* (SCH) (Thomason, 1997; Thomason & Kaufman, 1988). Framed in the premise that creoles are indicators of human interaction in unique and varying communicative contexts, they argue against a bioprogram, stating that children possess only enough a priori linguistic knowledge to give way for environmental and social conditions to affect acquisition in important and interesting ways. The SCH questions universal creole similarities, using comparative historical data as evidence that as a group, creoles maintain a range of structural differences, which cannot be a unique function of UG. Finally, the SCH points to pidginization as occurring abruptly, whereas nativization of creoles tends to be a gradual process requiring generations of participation from the community's child and adult populations in conjunction.

In light of the strong dichotomy often maintained between these two hypotheses, researchers appear to cursorily dismiss the possibility that the question is actually an empirical one. That is, the functions of the LBH and that of the SCH are not matters of ideological position but rather of scientific inquiry. The current model aims for a fuller understanding of the creolization process, based on an account that seeks to accommodate the operation of nature with nurture in language development. The methodology implemented in this approach relies on object-oriented programming techniques. As we suggest, SWARM provides an optimal tool for simulating the complex aspects of nativism and social contact that have fueled instances of historical language formation. Following Epstein and Axtell (1996), the proposed setting for language genesis functions as an *artificial society* that is able to "cultivate" creolized sentence structures *in silico* (in the computer). The primary goal of the model is then to examine the precise roles of theory-ascribed innate principles and socially based elements in generating prototypical creole grammars. As a result of this investigation, we hope to demonstrate that questions of creole genesis and general language acquisition may be most productively resolved through attention to the sociogenetic interplay.

OVERVIEW

This model simulates the activities and inhabitants of a group of real-world multilingual plantations that supplied optimal conditions for the growth of pidgins and the continued development of existing contact languages. It is important to note that although plantation-based slave labor tended to lead to creole genesis, it is not known if these languages necessarily originated from pidgin stages. Nor is creolized grammar an inevitable outcome of the plantation system. We will focus on one known context that is widely held to have spawned and perpetuated creole language (Siegel, 1987).

The ethnolinguistic and demographic parameters used in the current study derive from statistics on Sranan Tongo (Surinam Tongue) (Arends, 1995; Migge, 2000). Sranan is the native language of 200,000 inhabitants of modern Surinam and functions as lingua franca for the majority population. First language (L1) speakers of Sranan are largely descended from African slaves, but Surinam has a diverse ethnic pool that includes Amerindians, East Indians, Javanese, and other European groups. General background documents indicate that Sranan's earliest history began with mid-17th-century English settlers who set up small farms. By 1665, there were roughly 1,500 British planters in the region and close to 3,000 African-born slaves. Shortly following this settlement, a Dutch invasion occurred that virtually drove out all the English by 1680. Until 1690, the colony experienced accelerated growth as Dutch planters expanded farms into large-scale sugar plantations and imported increasing numbers of African slaves. By 1750, every planter-master owned 45 to 60 slaves. Plantation numbers were routinely decimated from slaves' lowered life expectancy, low birthrates, and escape. Records speculate that male slaves outnumbered female counterparts by a rate of 2 to 1. Children were 15% of the total slave cohort; approximately 40% of these infants died before age five. In short, the population was sustained through the constant influx of new slave labor rather than from natural growth.

Plantations typically functioned as strict hierarchical organizations. In Surinam, a large social distance existed between different groups on the plantation, causing considerable reduction in social networks. Social boundaries broke down along the following divisions: European versus African; adult versus child; elite slaves, including overseers and house slaves, versus field hands; and to a lesser extent, slave elites versus skilled African laborers.

In terms of linguistic history, it is quite interesting that the core vocabulary items for Sranan Tongo are essentially English, considering that Sranan speakers have been exposed to Dutch and various African languages for more than 300 years, whereas all L1 English speakers were expelled from Surinam by 1680. Although the lexicon is primarily English based, there are central words surviving from Portuguese, and a plethora of Dutch words have been steadily incorporated into the inventory. A number of lexical items are also taken from Javanese and Amerindian. Structurally speaking, the African grammar has had a widespread effect on the syntax and morphology of the language. The complete process of Sranan's development is murky, but it is relatively certain that initially, an English-based pidgin language was used in Surinam during the English planter era. There continues to be much discussion concerning the classification of the African linguistic influences. Ethnolinguistically, the imported populations that contributed to the formation of Sranan are said to link to a variety of language families on the western African coast. A primary substrate was formed stemming from early arrivals speaking Gbe and Kikongo dialects and from particular Bantu languages, which figured as a strong secondary influence in later periods, according to Arends's (1995) study. Based on demographic data, these substrate influences appear to be subject to frequent fluctuations, depending on the quantity and regional origins of slaves in the population at any given time. This said, the linguistic environment seems to have gradually moved to a more homogeneous state, as within a 70-year time period, the three language groups mentioned emerged as the most prominent in Surinam. A question that comes to mind is if these demographic conditions could have been the impetus for a new language form. Furthermore, might such factors cause the pidginized form of Sranan to creolize gradually or abruptly? I offer some insights in the upcoming sections.

RESEARCH PROGRAM

There are a number of agent-oriented computer efforts that examine aspects of the social sciences, which are relevant to the current inquiry. Schelling (1969, 1971) devised a simple spatially distributed model of the composition of neighborhoods, in which agents prefer that at least some fraction of their neighbors be of their own "color." More recent efforts in the social sciences build on larger scale, agent-based projects, such as works by Albin and Foley (1990), Axelrod (1993, 1995), and Resnick (1994). To my knowledge, there have been only scant attempts that bring these applications to bear on linguistic issues and even fewer models concerning acquisition in terms of languages in contact.[2] The current model conforms closely to Epstein and Axtell (1996) in creating an agent-based society.

Given the statistics presented in the previous section, each artificial society inhabitant is assigned a demographic profile designating age, race, health, death, cultural identity, and social status. Planters have the highest social standing, whereas slaves receive a status index based on their function in the plantation. Overseers have high status among slaves, and field hands and infirm slaves receive the lowest index. Upon reaching age 12, the child's status is assigned through random "inheritance" of one of his parents' indices.[3] The status index is essential, as it drives movement and subsequent language transmission, following the SCH.[4] Slaves' language variables are randomly assigned tags constituting different *A*(African)-*language* families. The planter language variable constitutes one *E*(European-based)-*language*.

Per LBH specifications, individuals have innate linguistic capacities. These endowments consist of several components: (a) a lexicon, or mental dictionary, represented as a list of values corresponding to each native and nonnative word stored by the agent; (b) a lexicon module for accumulating vocabulary items; (c) a list of derivational morphemes (building blocks of word formation); and (d) a list of grammatical morphemes (tense and plurality affixes on lexical items, etc.). Within the lexicon module, a morphology subunit accumulates the grammatical morphemes as a function L1. Sentence structure, or syntactic constraints, is represented as links mapping words and morphology in various ratios depending on language specified. A-languages are mapped three morphemes for every one word transmitted, whereas E-languages concatenate one morpheme per every one word. Agents process the linguistic input to which they are exposed by using bounded cognitive resources (e.g., memory and time). Following the LBH, children and adults possess different computational limitations for acquisition and storage of lexical and grammatical information (see Figures 1 and 2).

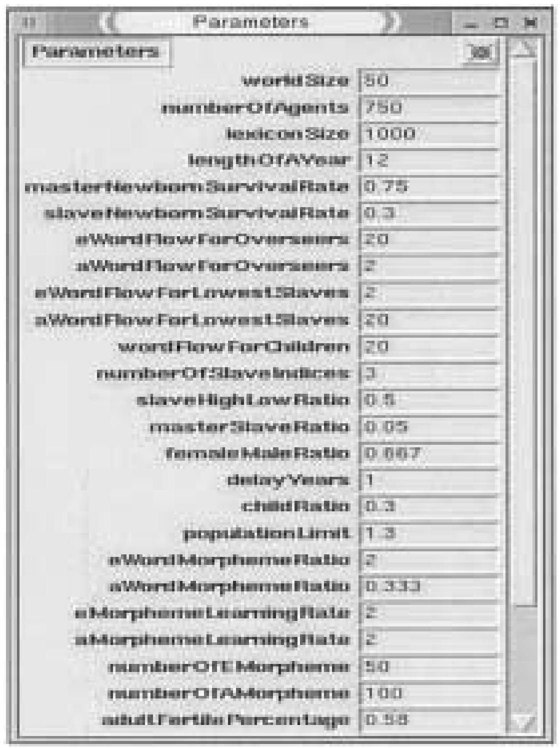

Figure 1: Model Parameters

DESCRIPTION OF THE SWARM MODEL

SWARM experiments generally involve three components: agents, environment space, and rules. Basic creolized systems are hypothesized to emerge as by-products of rule-governed interaction between agents operating in the established social environment. Distributions of innate linguistic knowledge, lexicons, and demographics are entered to initialize the population of agents. The temporary memory buffer prohibits adult learners from acquiring an unchecked amount of vocabulary, an analogy with the restricted computational resources of adult learners posited in much of the language acquisition literature. Child agents enter the environment with no linguistic affiliation but possess inherent capacities to store and generate any language. Children acquire both words and grammatical morphemes at higher rates than adults, following the LBH. Steps performed by the model are listed in Table 1.

SAMPLE RUNS AND RESULTS

The computer results reported in the following pages are based on the statistical information outlined. We test the robustness of the model by generating a range of probable speakers who were likely to exist throughout the projected stages of development of this particular creole. Three experiments examine the roles of nature and nurture in creole genesis, hence the primary experimental variables are child language acquisition mechanisms (LBH) and rates of social contact (SCH). For each test, the number of years of contact is given, as well as the linguistic profile of the community and an average of individual language patterns. As

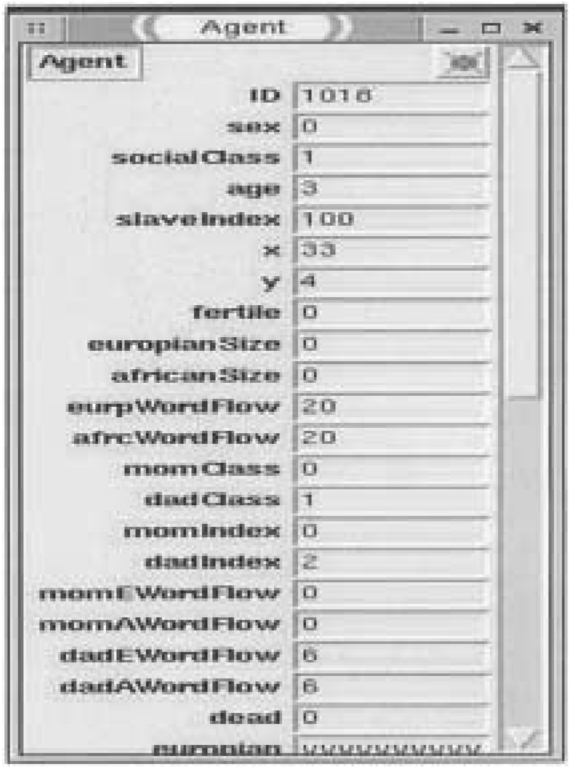

Figure 2: Agent Profile

TABLE 1
Language Learning Rules for Agents

1. Initialize *adult* (> 15.0 years) agent's distribution of language features and demographic features.
2. *Language contact*. Initialize random walk. (*1* chronological year = *12* cycles) Select unoccupied space within *X* Von Neumann neighbor agents.
3. *Language learning*. Talk to *X* neighbors. If input language = [+*African*], form probability of encountering lexical and morphological information based on population ratio of African languages: Language *A*, Language *B*, Language *C*, other African languages.
   A. Adult:
   If neighbor has [> status index], look at *X* words in his lexicon. If you do not find those words in your lexicon, select those *X* items and copy into your temporary memory buffer. Talk to *X* neighbors during this step. Consult temporary memory buffer. Add new vocabulary item(s) to your lexicon only if you encounter > *2.0* instances of those new words.
   B. Child:
   If neighbor has [> status index], or if he is a child > *5.0* years, look at *X* words in his lexicon and *Y* morphemes in the morphology listing. If you do not find those words and morphemes in your lexicon, select items and copy them into your respective lexical and morphological storage units. Talk to *X* neighbors during this step. Add new vocabulary item(s) and morphemes to storage areas immediately when you encounter *1.0* instance of new word *W* and new morpheme *M*.
4. Language learning for current cycle completed.

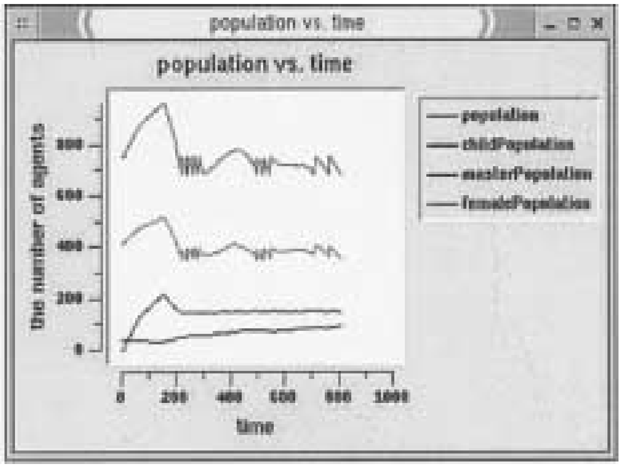

Figure 3: Population Distribution

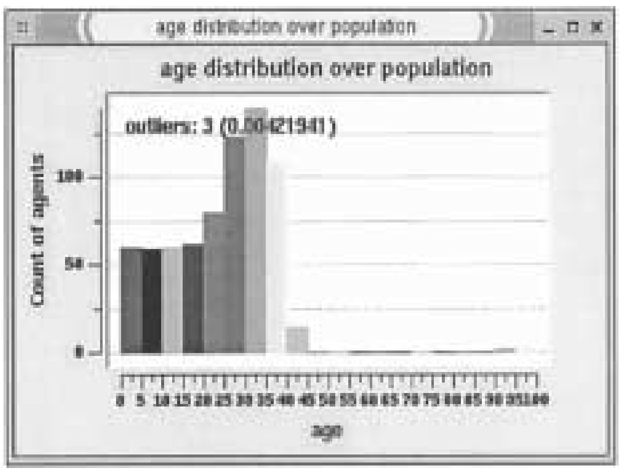

Figure 4: Age Distribution

illustrated in Figures 3 and 4, population and age distributions are continuously monitored during the process.

Experiment 1

In Experiment 1, all variables were kept constant; subsequently, elements of the SCH (translated as high-frequency and high-quality social contact) and the LBH (translated as biologically endowed linguistic mechanisms) are assumed maximally operative. The end result is indicative of a setting composed of a 15% minimum of children and unlimited contact (per appropriate social hierarchies) between neighbor agents. Figures 5, 6, and 7 display results.

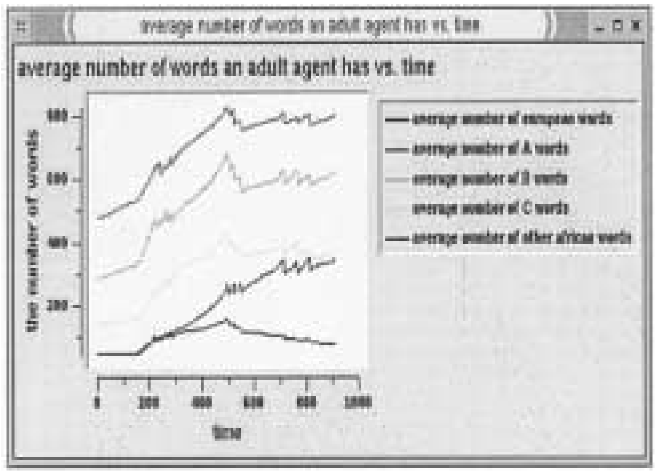

Figure 5: Adult Lexical Storage

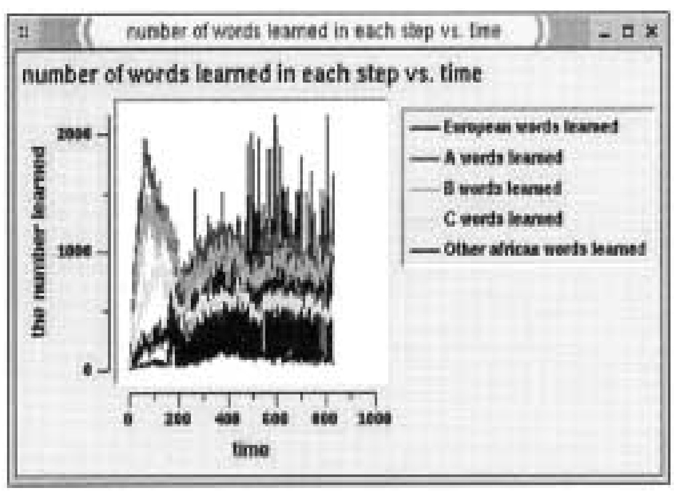

Figure 6: Lexical Items Acquired

Experiment 2

Experiment 2 manipulates the social contact variable to examine the degree of the SCH's impact in creole formation. Instead of unlimited access to linguistic information from all surrounding neighbors of appropriate status, agents are permitted to interact with one neighbor per cycle. Results may predict whether creole genesis is possible with minimal agent interaction. Graphs are shown in Figures 8 and 9.

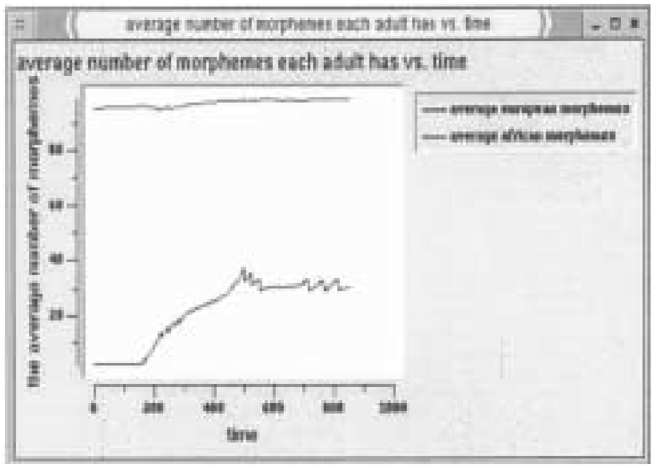

Figure 7: Adult Morphemes

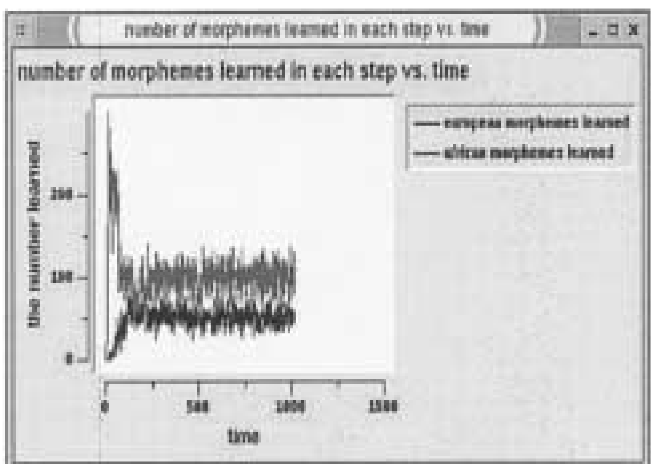

Figure 8: Morphemes Acquired No Social Context Hypothesis

Experiment 3

Experiment 3 manipulates the child-driven language variable to investigate the LBH's role in creole formation. In this scenario, no children are born into the population. Adults exclusively are interacting in this context, with speaker numbers maintained through periodic importation of slaves into the contact setting. Findings may predict whether creole genesis is possible in the absence of child learners. Results are presented in Figures 10 and 11.

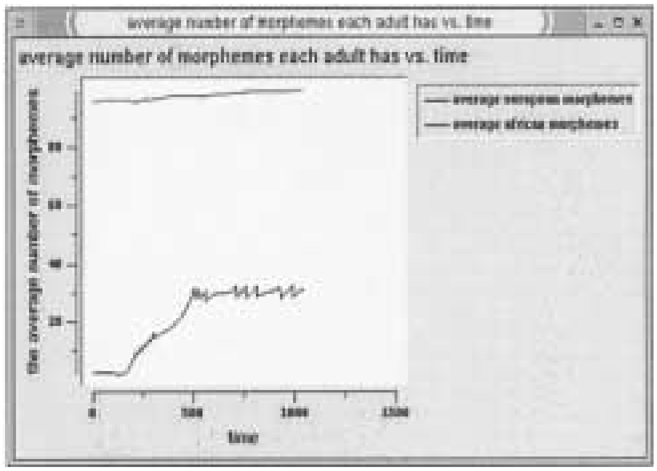

Figure 9: Adult Morphemes No Social Context Hypothesis

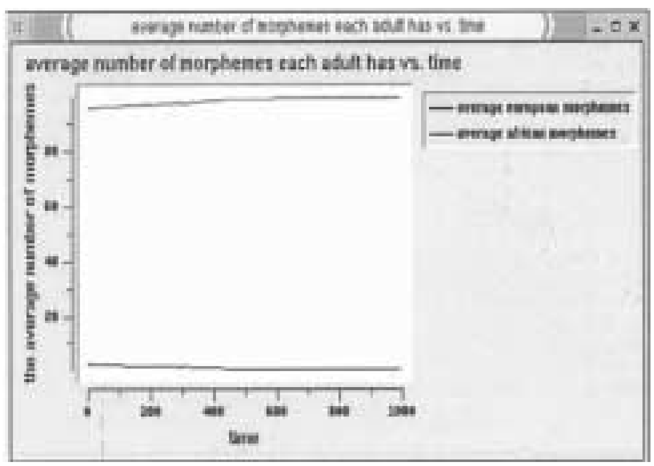

Figure 10: Adult Morphemes No Language Bioprogram Hypothesis

Discussion

Experiment 1 produces dynamic characteristics that one would equate with language change scenarios. After three generations (approximately 70 years), Figure 5 demonstrates how E-language words come to gradually replace certain A-language varieties, as documented in real-world plantation history. In line with historical slave language pidgins, Figure 6 exhibits initial trends of an abrupt overlapping of A-language-acquired lexical items. The presence of children shortly after Cycle 100 brings an "averaging" effect for the acquisition rate. An explosion of E-language vocabulary emerges in part from the fact that children require less frequency and memory to retain new vocabulary items, but, apparently, also from the influx of younger slaves from Africa, seen shortly after Cycle 200 and again at Cycle 450. It is well to note that stored morphemes of the respective languages are natively

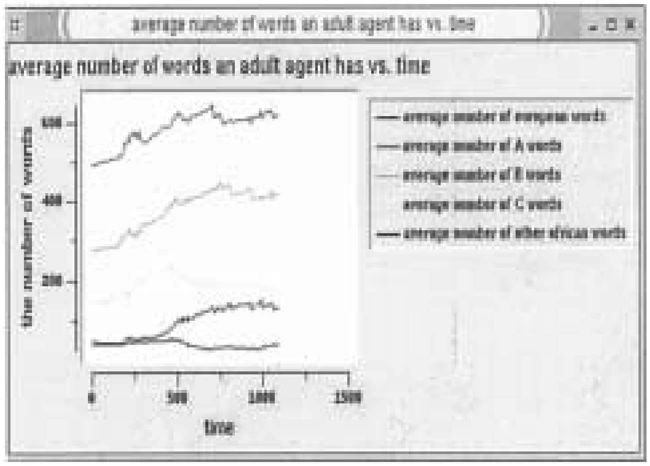

Figure 11: Adult Lexical Storage No Social Context Hypothesis

complete and distributed across the language groups, as displayed in Figure 7. If it is the case that inflectional morphology is acquired entirely as a function of first language acquisition by children, a feasible explanation for the gradual storage of increased non-African morphology might be found as an effect of the population of European planter children. Paralleling the historical facts, White children, older than 8 years, have more contact with European adults than do the other groups. To the degree that this conjecture is correct, E-language morphemes acquired by the planter children in mid- to late childhood could still be easily transmitted to younger children with whom they are in contact. Consistent with the data, we find that speakers in this scenario possess a diminishing A-language vocabulary, with substantive, but separate knowledge of both A- and E-language grammatical properties derived from childhood interactions.

Experiment 2 examines creolization in a population of adults and children, under limited social interaction. Figure 8 shows that the initial short-lived rise of A-language morpheme acquisition gives way to E-language morphology acquired at slightly lower rates than A-language forms. The learning pattern is relatively robust despite limited contact; however, we can attest that morphologies of each language do not overlap or combine as the learner acquires stable quantities of A- and E-language morphemes. Figure 9 displays results nearly identical to those found in Figure 7 for the morphological storage in an adult speaker. Again, the agent has maximum knowledge of both A- and E-language grammatical properties. In the face of restricted interaction, Figure 12 illustrates that lexical acquisition is 50% less under limited contact than the rates obtained in Experiment 1. A-language (precisely, African language A) forms are acquired at a prominent rate throughout the test, overlapping with E-language activity in the final cycles. Figure 13 tracks adult lexical inventory states and shows that similar to Experiment 1 findings, E-language words gradually replace certain A-language varieties; however, A-languages still comprise the majority of words stored. Again, we find that changes are minimally induced in the linguistic knowledge base. An adult's profile in this scenario corresponds to a small and receding A-language lexicon, which is slightly more A-dominant than the outcome of Experiment 1, because the probability of interacting with E-language speakers becomes more remote, given fewer overall contact possibilities. The data also show substantive but separate knowledge of both A- and E-language grammatical properties in the adult agent.

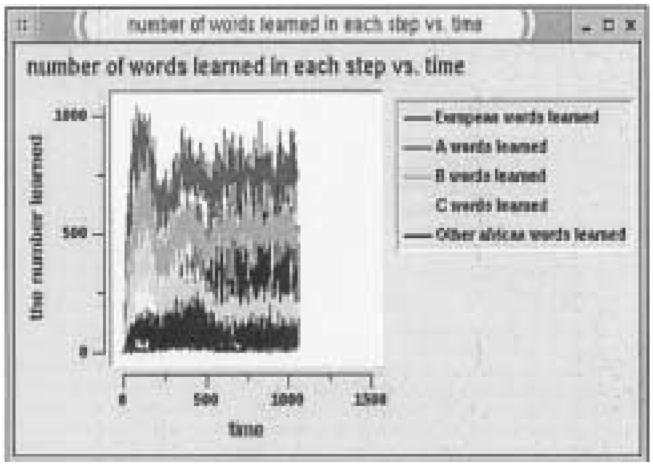

Figure 12: Lexical Items Acquired No Social Context Hypothesis

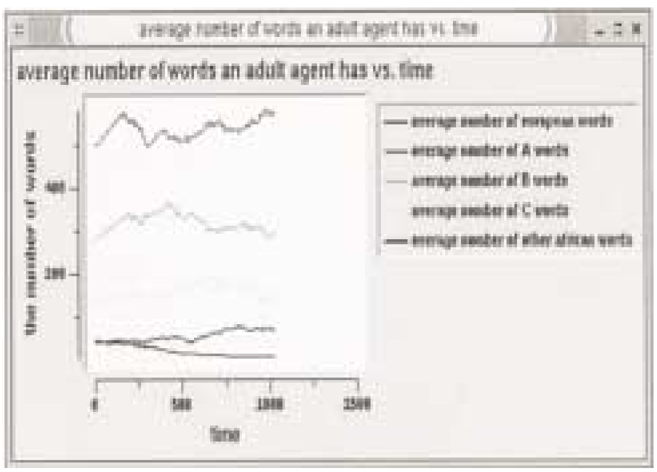

Figure 13: Adult Lexical Storage No Social Context Hypothesis

Experiment 3 reflects a full-contact scenario in the absence of child language. Figure 10 shows the adult speaker with a full storage of A-language morphemes; however, contrasting with Figures 7 and 9 in contexts that do involve children, Figure 10 displays no presence of E-language morphology. Figure 11 signals that A-language lexicons come to completely dominate E-language vocabulary; the latter falling to zero within 1,000 cycles. Thus, we gain important preliminary data on the role of children in the transmission of language features. Empirically, A-language words in Experiment 3 are stored at the same quantities found for Experiment 2 (see Figure 13), with a slight exception for the largest spoken A-language. It is interesting to note that when no children are present, adult speakers in Experiment 3 appear to also maintain languages that are the least influenced by contact. These agents possess a small-sized vocabulary, exclusive to A-language words, a few that may have been acquired from others. These speakers have full knowledge of solely A-language grammatical properties, those being present as L1 features.

Statistically speaking, the data show that Experiment 1 represents the most fertile conditions for hypothetical creole genesis because active child populations and relatively unrestricted contact trigger the highest incidents of aspects of language change. Although patterns in Experiment 2 did not differ extensively from those in Experiment 1, limited contact appears to affect most dramatically the quantity (and perhaps quality) of lexical items acquired and stored, while having minimal influence on the acquisition rate of morphology. Experiment 3 deviates greatly from the projected creolization outcome, as the lack of children in the linguistic environment equated to a near-zero rate of feature transmission over time among the distinct adult language groups.

CONCLUSION

In attempting to build from formulations of the LBH and SCH, the aim of this empirical investigation was to begin to duplicate the complex nature of historical creolization, simultaneously following social patterns and (biological) linguistic development in a plantation setting. Preliminary evidence from the simulations demonstrates that genetic and social mechanisms must function bilaterally, each contributing and maintaining its specific properties and proportions in the acquisition task, if optimal conditions are to be met for the emergence of a prototypical creole grammar.

More precisely, our findings suggest that innately specified capacities do indeed play a crucial role in allowing children to organize disparate input in such a way that this information can be subsequently accessed to create novel and complex structures, in computations that adults do not seem to use. Notably, striking similarities in the morphological acquisition patterns of Experiments 1 and 2 strongly favor the LBH claim that extralinguistic factors and the environment do not greatly influence grammatical (inflectional) acquisition (Chomsky, 1995). Insofar as this is the case, such results may also unwittingly serve to contradict the conservative “bet-hedging” premise of the LBH. Speakers retained native levels of all grammatical morphological items in both language groups, much as one would expect in a bilingual acquisition scenario, instead of constructing a more generic pattern of morphology across languages (Satterfield, 1999). In provisional support for this aspect of the LBH, it may still be argued that the child’s threshold for acquisition of inflectional elements is lower or in some way easier to attain than for derivational morphology and full vocabulary.

The results also suggest that a higher-than-“normal” level of social interaction is necessary to acquire a uniform threshold of lexical inventories that can then initiate the creolization process (e.g., begin to activate access to the organized system of dissimilar inputs). In other words, without a certain quantity of lexical or derivational morphemes, whose acquisition seems linked to an optimal amount of social contact, all of the disparate stored inflectional elements will still not be useful, in and of themselves, in producing creolized computations. Instead, a competing language, or survival of the “fittest” scenario, is more apt to transpire among the distinct inputs. Furthermore, as disputed under the SCH, no experiment validated the LBH claim that creole languages develop within a single generation of child speakers. With roughly four generations of agents, comprising more than 1,000 runs in differing population configurations (+/-children), few mixed language forms materialized.

I can only conjecture that perhaps as a consequence of not meeting conditions in the exact proportions needed, extensive nativized amalgams across A- and E-languages were not elicited in the model.[5] Given these tentative empirical findings, I advance a sociogenetic solution for analyzing questions related to creole genesis.

Motivated by theoretical and practical concerns, modifications to the research program are presently being considered, with an eye to providing more explanatory models of language contact. For example, a syntactic formation involving fixed templates of *X* words to *Y* morpheme affixes is not suggested by current linguistic theory, although this strategy efficiently eliminates extensive searches for language family tags. Second, we posited rigid constraints on adult acquisition of nonnative words and morphology, whereas the youngest children had few restrictions for storing any morphological or lexical item. It is clear that such stipulations, along with issues of linguistic input, must be precisely coordinated with recent findings in first and second language acquisition theory. Last, demographic factors, such as accurate information on the European groups and their language patterns on the plantation, should be fine-tuned to better pinpoint those critical-mass conditions necessary for triggering individual and population-wide creolization over time.

NOTES

1. I use the term *pidgin* not in the detrimental sense attributed to it in many standard dictionaries but in the technical linguistic sense, as a type of auxiliary language or strategy that is called upon by speakers in addition to their own native languages to enable communication to take place.

2. See Kirby (1998) for a notable exception. See also Briscoe (2000).

3. Offspring can only receive planter status if both parents are planters; if one parent is a planter, the child receives a slave index.

4. Given sociolinguistic studies (Gumperz 1971), socioeconomic status appears to play a role in language transmission.

5. This said, in those cases limited to A-language inputs, the African languages appear to gradually reduce to a commonality of structures. This effect could be due to an elimination of redundancy across these languages, not necessarily a creolization of distinct elements.

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