BACK TO NATURE OR NURTURE: USING COMPUTER MODELS IN CREOLE GENESIS*

Key words: Language acquisition, Creole Genesis, Computational Models

ABSTRACT

"Artificial societies" are constructed to examine L2-based creole development. 'Virtual' slaves and slave-owners interact based on socio-historical conditions. Linguistic transmissions and developments are tracked. This study takes no position on whether a theory of 'imperfect L2 acquisition of the superstrate language' can be viewed as final truth with respect to creole genesis. However, a Complex Adaptive System approach sheds light on underlying dynamics of the canonical plantation which produce large-scale effects. Our findings suggest that patterns of adult L2 acquisition presumed under standard L2 creole accounts are not sufficient to explain the emergence of these creoles. Adults in our model created an incipient African-based pidgin which continued with each generation of L2 speakers. Notably, in a previous study we found that 'prototypical creole' structures emerged when a very small percentage of older bilingual children were present in the population.

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INTRODUCTION

Various hypotheses offer explanations for how creole languages arose in language contact settings, such as a plantation scenario. Accounts such as the Language Bioprogram Hypothesis (LBH) (Bickerton 1981, 1984, and others) argue that these types of creoles arise within one generation when children create a novel first language (L1) due to exposure to their immigrant parents' pidgin input. A contrasting view supports the notion that these creoles are manifested by adults when their 'unsuccessful' or imperfect attempts at second language (L2) acquisition converge to a new code (Chaudenson 1992, 1995; Arends 1995, Mufwene 1996, among many others). A long-standing challenge has been how to reliably test theories concerning the origin and evolution of historical creole languages, owing to imperfect records and the extinction of intermediate forms.

A central premise in our research program is that language acquisition, cognition and culture can be fruitfully analyzed as complex adaptive systems (CAS), particularly given complex sets of linguistic processes mediated by internal and external factors which extend across multiple timescales (e.g., Satterfield 1999, 2001, 2005). A CAS is a dynamic network whose emergent properties are produced bottom-up by the simple interactions of many individual elements. A CAS is complex in that it is diverse and made up of multiple interconnected units; it is adaptive in that it has the capability to evolve and to learn from experience within a changing environment (Holland 1998). While the CAS approach has been applied in several linguistic studies concerning aspects of evolution leading to human language (Steels 1997, 2005; Briscoe 2002, 2000; Culicover and Nowak 2002, Kirby 1999, etc.), the present study demonstrates how the concept of CAS is also relevant for modeling natural phenomena observed in real-world language acquisition, and providing a window into linguistic development at several levels of analysis. At the local level, the existing *I*(nternal)-*language* grammar, that is, the mentally represented linguistic knowledge within the mind of each speaker, can be presented. Dynamic interactions of individuals in turn generate collective linguistic representations at the global level, where the adoption of a particular *E*(xternal)-*language*, the body of linguistic knowledge or behavioral habits as manifested in actual instances of language performance of a community, is constructed.

Because the CAS dynamics generated in the interaction of numerous socio-cultural and cognitive variables are too complex to solve analytically, we analyze these properties within computational models, which provide methods for systematically examining the concurrent formation of social patterns and psycholinguistic structures as they develop within that history.

Moreover, it becomes possible to tease apart the contributions for each respective variable. In addition to generating informative empirical data that is valuable to language investigations, this particular computer model brings to light underlying assumptions concerning formal language acquisition hypotheses, thereby helping to assess the plausibility of the proposals being advanced.

The objectives framing this study are entirely practical. First, we seek to model basic demographic and socio-cultural information associated with a well-known creole language scenario. For this goal we adopt Sranan Tongo (Arends 1995, Bruyn 1995, Price and Price 1992, Van den Berg 2000, Winford 2003, among others) as our base case for calibration of the computational model. Secondly, we use this experimental environment to explore the L2 hypothesis on the formation of plantation (Atlantic) creoles in greater detail. We utilize local-level artificial agents (computer-simulated robots) (e.g., Epstein and Axtell 1996, Ferber 1998, Fox-Keller 2002) with diverse social and linguistic repertoires to inhabit our artificial society.

In terms of demographic and socio-cultural features, children undergoing L1 acquisition are not included in the current experiment, even to the degree that they would presumably interact with and affect adult L2 acquisition. In this vein, the present work diverges from Bickerton (1981, 1984), who makes an intriguing case for a nativist perspective of language acquisition in terms of the LBH, which places primary importance on a child's inherent predisposition to acquire language (crucially, the L1).[1] Bickerton's view has not been widely adopted in the creole studies literature; moreover, Arends (1995:268), among others, assumes that the presence of children was statistically inconsequential (consistently less than 20 percent) in early Surinam, and therefore L1 child-language is argued to have no enduring structural effect on emerging creoles such as Sranan.

Perhaps more thought-provoking is Bickerton's analysis spanning a range of creole languages and the structural properties that they are postulated to share. According to the guiding premise of the LBH, the similarities can best be explained by the existence of a species-particular and universal biological "blueprint" for language acquisition. Strong empirical support for the LBH with respect to the specific properties predicted to emerge in creoles due to LBH effects has not materialized. However, the general framework of the LBH in which the child's capacities in (L1) acquisition differ markedly from those of the adult in (L2) acquisition has proven to be sound and is largely compatible with the views of most language acquisition specialists. In this spirit, general cognitive and psycholinguistic specifications, adult L2 features such as bounded processing (e.g., limits in working memory, slower processing rates, reduction of inhibitory mechanisms, etc. per Johnson and Newport 1991, Strozer 1994, Miyake and Shah 1999), and limited acquisition of L2 inflectional morphology (Hudson-Kam and Newport 2005, Lardiere 2000, etc.), are integrated into the model.

Our central objective is to determine, given the conditions outlined, whether the interaction between multiple agents in this specific communicative context indirectly results in the formation of new linguistic (creole) structures. As the CAS organization is emergent rather than pre-determined, the agents in this scenario might end up with quite different linguistic repertoires than the historically documented human case, yet it is extremely thought-provoking to investigate whether the agents can arrive at the attested creole solution, based precisely on the conditions advanced under a specific L2 account of creole formation.

BACKGROUND

We adhere to 'standard' definitions of a *creole* as a contact language that emerges when speakers of mutually unintelligible languages must communicate with each other (Arends, Muysken, and Smith 1995; Holm 2000; Mühlhäusler 1997; Sebba 1997; Thomason 1997, 2001; and Winford 2003). In this context, the adults learn a small number of lexical items of the dominant language (the superstrate); however, they do not completely master the superstrate's grammar. Frequently a new language comes into being, and in its earliest stages is known as a *jargon* or *pidgin*. Pidginization is a process involving (linguistic and functional-communicative) reduction, often characterized as a continuum ranging from periods of highly unstable L2 jargons to extremely stable phases with expanded pidgins. If a pidgin becomes widely accepted in the community and its use more stabilized and diffused, the resultant language is known as a *creole*. In contrast to pidgin formation, the emergence of a creole is prototypically a process of expansion that generates quite a different grammar than previously exhibited by speakers in those linguistic surroundings. While plantation-based slave communities tended to lead to creole genesis, a creole grammar was not an inevitable outcome of the plantation system. Nor is it known if these contact languages necessarily originated from pidgins.

From our assessment of the creolist literature, L2 acquisition is often depicted along a continuum, where 'absolute' attainment of the L2 target is regarded as largely indistinguishable from the monolingual adult native speaker. When absolute attainment is not achieved, the 'imperfect' L2 outcomes can produce a creole, either in the form of a new L2 grammar or an interlanguage variety of the target (e.g., Chaudenson 1995, Gross 2000, Singler 1996, Thomason and Kaufman 1988). Chaudenson's (1995) account describes impoverished linguistic access as a catalyst for L2 creole development. With time, newly arrived adult slaves were no longer exposed to the original superstrate variety of French, but instead learned 'approximations' of L2 target grammars from the already acculturated adult slaves and L2 varieties of other recently imported slaves. For the most part, the L2 creole hypothesis operates along three overarching tenets:

- The formation of the prototypical creole is viewed as gradual (e.g., spanning multiple generations) and non-nativized (e.g., based on E-language formation largely in L2 speakers of the community). [2, 3]

- There is "…broad consensus that the role of UG is to constrain the processes of restructuring by which superstrate and substrate inputs (intakes) are shaped into a viable grammar—one that conforms to universal principles of language design (Winford 2003:347)." Thus, the idea of L2 acquisition as UG-constrained may be compatible with a view of (imperfect) input-driven learning, insofar as UG does not eclipse critical external or social elements in shaping the creole grammar.

- "...Creolists generally accept that creole formation was primarily a process of L2 acquisition in rather unusual circumstances (Winford 2003: 356)." We understand 'L2 acquisition' to refer to mainly adult speakers, and 'unusual circumstances' to be due to atypical external (social) factors such as slavery.

A general consensus in L2 acquisition references is that adults display varying degrees of L2 attainment (by monolingual native standards), even when possessing considerable motivation and resources. That linguistic capacities diminish or are not fully attainable over time is richly attested in the psycholinguistic literature, particularly with respect to specific domains of linguistic knowledge: phonemic contrasts (Werker and Desjardins 1995), sentence-processing (Weber-Fox and Neville 1996), syntax and the mastery of inflectional morphology (O'Grady 1999, Sorace 2003, Ganger et al. (in press); Johnson and Newport 1989, 1991; Lardiere 1998a, 1998b, 2000; Lightbown 1983; Sorace 2003, etc.), and semantic contrasts (Larsen-Freeman and Long 1991). [4] Generative L2 research has found considerable similarity with L1 acquisition and evidence of Universal Grammar (UG) availability (Flynn 1987; White 1989, 2003, etc.), but there is also significant counter evidence to UG availability claims (Bley-Vroman et al. 1988, Clahsen and Muysken, 1989, etc.).

We hasten to add that no study reports that adults cannot learn the L2 in any capacity whatsoever. Rather, the adult norm is a high level of mastery in areas such as lexical acquisition and idiomatic expressions, with much lower proficiencies in L2 pronunciation, details in phrase structure and in certain inflectional aspects. Following a CAS approach, it is possible to argue that since L2 acquisition entails complex interactions of multiple external and internal factors varying for each individual, an endpoint in language learning abilities cannot be isolated strictly by age. Singleton and Ryan 2004 (and authors within) find that in naturalistic learning situations, those whose exposure to the L2 begins in adulthood show initial advantages in areas such as syntax and language processing over those whose exposure begins in childhood. Nevertheless, research findings generally demonstrate that younger learners come to surpass adults in L2 proficiency. Singleton and Ryan et al. (ibid. cit.) concede this point, but assert that the apparent lack of overall attainment for adults in the L2 has nothing to do with maturational constraints, and everything to do with language input and usage within the context of sociolinguistic and socialization norms. These authors conclude that early exposure to the L2 is important, not necessarily due to maturational factors, but simply because the earlier one starts in L2 acquisition, the more contact one gets with the target. Since the L2 access premise is central to many L2 acquisition and L2 creole formation approaches, it will be a critical experimental variable in the current work.

CASE STUDY

Descriptions

Our aim is to model the historical conditions that presumably led to the development of Sranan over time, and to determine whether the inhabitants of the artificial society form L2 grammars that reflect any or all of the properties found in the stable Sranan creole. The demographic and ethnolinguistic criteria utilized in the current work derive from a compilation of historical archives and linguistic accounts on Sranan, an English-based creole (Arends 1992, 1995; Braun and Plag 2003; Bruyn 1995; Migge 1998, 2000; Seuren 2001; van den Berg 2000; and Winford 2000, 2001, 2003).[5]

Linguistic Features

Sranan exhibits several properties prototypical of other creoles: highly impoverished grammatical (inflectional) morphology, as the verb form is the same for all tenses, moods, and persons; the marking of tense, mood, aspect (TMA) and negation by means of pre-verbal particles, reduplication, and canonical SVO word order in declarative and interrogative constructions, among other features. Given the current model's parameters (to be specified in detail in the upcoming sections), a possible linguistic outcome of adult speakers' interactions over time might yield strings such as those below:

1. a. Mi no ben si en.
1st sing not past see 3rd sing
"I did not see him."

b. Psa te unu kaba nanga skoro dan wi o meki pikin nanga den sani dati
c. only when we finish with schooling then we future have baby and plu.def. art thing dem. pron.
"Only when we finish with school, then we'll have kids and all those things."

d. Ma yu nelde yu mama dati wi e go prei bal?
but 2nd sing prog 2nd sing mama that we prog/hab go play ball
"But have you told your mom that we're going to play basketball?"

e. Dan te mi miti en mi sa aksi en.
then when 1st sing meet him 1st sing fut ask him
"Then when I see him I will ask him." Winford (2001)[6]

Sranan's lexifier language is essentially Early Modern English.[7] Concerning the African substrate influences, Arends (1995) links the formation of Sranan (and perhaps additional Surinam creoles) to a variety of language families on the western African coast, providing the

TMA elements and other grammatical information. A primary substrate likely formed stemming from early arrivals (1650-1720) with 50% of imported slaves speaking SVO languages of the Gbe-cluster (Fon, Ewe), and 40% from particular SVO (and options for SOV in certain contexts) in Bantu languages (e.g., Kikongo) which figured as strong secondary influences. From1720-1740, imported slaves spoke mainly Gbe and Kwa from the Nyo-branch. The relevant African languages most likely contributing to Sranan post-1740 are Fon (along with the other closely related Gbe-languages), Kikongo, and, to a lesser degree, Twi (belonging to the Kwa group). Based on Arends' (1995) data, the substrate influences were subject to frequent fluctuations, depending on the quantity and regional origins of slaves in the population at any given time. However, the linguistic environment gradually moved to a more homogeneous state. Within a 75-to-90-year time period, the post-1740 African languages emerged as the most prominent in Surinam

We posit that an emergent grammar resembling modern Sranan should exhibit similar characteristics, which we simplistically term '*prototypical creole effects*.' If such properties are observable as the output of the computational model, they should minimally include the following: SVO word order paralleling both English and most of the substrates, a largely European (English) lexical superstrate, and African language substrates in the form of (limited) inflectional morphology.[8]

Social Features and Demographics

There are many unanswered questions concerning historical aspects of (the Atlantic) creoles (a reason in itself to carry out computer modeling). As Arends' is generally acknowledged as an authority on the linguistic history of Surinam creoles due to his painstaking historical research and careful tabulations, we closely adhere to his projections. Based on Arends (1995), Sranan's earliest history arose from the language contact situation with English, Dutch, and a few French settlers who set up small farms utilizing African slave labor from 1600-1650. At this time, roughly half of the European settlers were British. By 1665, there were approximately 3,000 African-born slaves laboring in the region, and close to 1500 permanently installed European planters. This early 2:1 ratio of blacks to whites may have set the stage, as Chaudenson (1995) asserts for comparable eastern Atlantic settlements, for a preliminarily successful absolute L2 acquisition model. However, a more heterogeneous European population consisting largely of the Dutch and English must be taken into account in the case of Surinam. A Dutch coup occurred in 1667 and within 13 years, a mass exodus of the majority of English colonists and, perhaps the slaves acquired by them, took place in Surinam. From1680-1700, 18,000 slaves arrived in Surinam, with similar rates of importation each year after until the 19th century. The proportion of Africans to Europeans rose from 2:1 in 1665 to 20:1 in 1744. Plantation numbers were routinely decimated from the slaves' short life expectancy, low birth rates, and escape. Healthy males were the preferred commodity of slave-traders (Kay 1967), with males outnumbering female slaves about 2:1. Due to the small numbers of females in the population and high mortality among slaves, the slave populace was sustained through the constant influx of new African labor, rather than from natural growth.[9]

Arends (1995:21) predicts that, "the model for the acquisition of the creole as a second language by the African-born slaves would be a second, not a first language version of that creole," yet this claim of L2 approximation may not fully take into account certain general social and communicative factors no doubt operative in the plantation setting. Owing to the fact that over time the Atlantic plantations functioned as increasingly hierarchical organizations, some social distance existed from early on between various groups on the plantation, causing restriction in social networks. In terms of language contact in 17th and 18th century Surinam, the possibility of gaining access to the linguistic variety with the highest prestige would have been distributed differentially, instead of across the board approximation of L2 models for all slaves. Social stratification likely occurred along the following boundaries in the plantation: European versus African; older versus younger; elite slaves, including overseers and house slaves, versus field hands; and to a lesser extent, slave elite with diminished manual tasks versus highly skilled

African craftsmen (Valdman 2000). These divisions invariably produced linguistic consequences, since they created a clear incongruence in social status within the general population and more critically, within the slave community.

Only if the language of prestige is taken by all speakers to be that of the slave owners, does it become possible to obtain Arends' (1992) and Chaudenson's (1995) adult L2 acquisition scenario where directly or indirectly, the European language is the target. In this case, one must accept the presupposition that field slaves intrinsically wished to acquire the L2, and their limited access to the target would presumably lead them to preserve elements of the L1 African languages. Accordingly, low-status adult speakers such as the field workers would create a *basilect*, a creole typologically removed from the English superstrate. Adult house slaves, may attain near-native L2 proficiency, but were more likely to acquire a creole *acrolect*, which increasingly conformed to the prestigious European superstrate.[10] However, implications for adult L2 acquisition must also be considered in terms of the contact between speakers of the numerous African languages as well. This hypothesis becomes more critical, if as Valdman (2000) suggests, certain African languages were purposely maintained for particular slave tasks.[11] Insofar as a primary substrate stemmed from early slave importation (1650-1720), approximately 90% of these arrivals spoke Gbe-cluster and Bantu family languages. Due to sheer numbers these language groups may have had considerable linguistic prestige among the slaves, further lessening the need to develop a new lingua franca when access to the superstrate was already limited.

EXPERIMENTAL SYSTEM OVERVIEW

Components of the model

The language contact scenario is constructed with a generic software platform known as SWARM. The basic properties of CAS are encoded via the following computational components: environment/space conditions, agent specifications, and local rules both for the environment and for agent actions. Each element is briefly described below.

Environmental specifications

Features specified for this environment include the landscape, or search space, as the spatial boundaries of the model. The space is made up of a 50 x 50 square lattice that holds 2500 slots. Agents appear as color-coded squares representing five different African and European populations, shown in Figure 1:

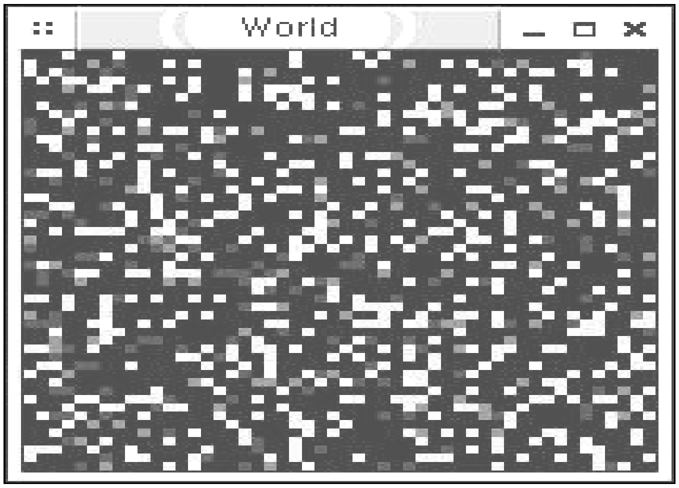

Fig. 1. World (Population of Agents) as 50 x 50 square lattice holding 2500 slots. Agents are color-coded squares representing five different African and European populations (Color-coding in this and subsequent figures has been removed for publication).

The total population has a 2500-person carrying capacity (specified as the *population limit rule*). Parameters implemented to inform population makeup are based on historical statistics of Surinam social affiliations (Arends 1994, 1995). Demographic features and E-language aspects implemented in the model, along with their respective values, are in Figure 2:

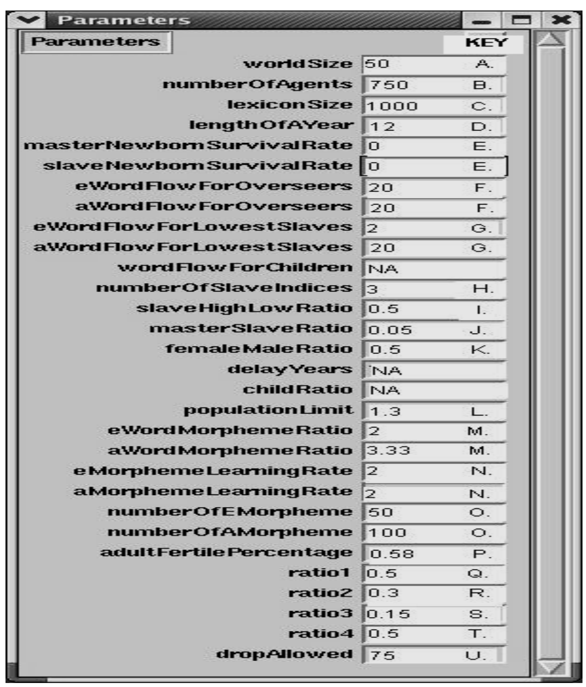

Fig. 2. World Parameters (External and Internal Environment Profiles). Refer to text for detailed discussion. KEY: A=physical dimensions of landscape; B=current population; C=current maximum capacity of lexicon; D=number of iterations representing one year; E=infant mortality; F=maximum number of European/African forms constituting a sentence in Overseer speech; G=maximum number of European/African forms constituting a sentence in Infirm (lowest status) Slave speech; H=number of cultural tracking “tags” assigned to a Slave Agent;

I=maximum proportion of high-status to low-status Slaves; J=maximum proportion of SlaveOwners to Slaves; K=maximum proportion of all males to females; L=maximum population capacity; M=maximum number of European/African affixes possible with a word/stem; N=maximum number of European/African affixes depositable in working memory during any given exchange; O=maximum number of European/African affixes available for acquisition; P=proportion of adults with reproductive capacity; Q=maximum proportion of Gbe-cluster speakers in the population; R=maximum proportion of Bantu language speakers; S=maximum proportion of Kwa-group speakers; T=maximum proportion of other African languages; U=maximum number of Agents that can be "eliminated" each iteration (10% of current population).

Theoretical and cognitive variables of the model

Bounded resources are encoded as part of the agent's internal (cognitive) 'environment'. We assume the existence of a language faculty (FL) realized as the speaker's capacity for generating and analyzing linguistic structure (e.g., Chomsky 1995, 2000, 2002; Jackendoff 1997, 2002, Sharwood-Smith and Truscott 2005) [12]. In its most simple instantiation (per Chomsky 1995), the FL houses a peformance system and a cognitive system. The cognitive system constructs linguistic derivations based on morphological, phonetic-phonological, semantic and syntactic information. The derivations are used as output that is made available for interpretation at the sound and meaning interfaces of the performance system. More specifically, the cognitive system contains a lexicon and a computational system (C_{HL}). The lexicon generates the items utilized by the C_{HL} to build linguistic derivations according to the grammar specified. The agent's lexicon is a repository of both word-size and smaller units (stems and affixes). We further delimit the lexicon into two storage compartments: a morphology unit housing inflectional morphemes and/or preverbal tense, mood, and aspect (TMA) markers, as a grammatical function of the learner's L1; and a second unit for storage of word stems.[13] Figure 2 lists *eWordmorpheme* and *aWordmorpheme* ratios constituting word formation rules, in the form of the maximum number of affixes, European or African, permissible with the transmitted word stem. For this model, lexical rules apply to derive regularized African and European forms only. African languages are mapped three grammatical (TMA) preverbal markers to every one lexical item, based on general typological properties of Gbe dialects, such as Fon (Fabb 1992; DeGraff 2002, 2005). Insofar as the preverbal particles display agreement and Case information, and rigidly precede the verb with no intervention from other items, they constitute inflectional morphemes. European languages are represented as two bound inflectional affixes per stem, based on morphosyntactic properties assumed for Early Modern English.

We posit that newly encountered items are first stored in working memory (temporary memory buffer). The M*orpheme Learning Rates* regulate the maximum number of African or European morphemes deposited in working memory during any given exchange, whereas the *number of Morphemes* provides the upper-bounds on the array of respective European and African morphemes available and learnable for the (input) grammars. The *lexiconSize* specifies the size of the new stems and affixes housed in storage.[14]

WordFlow exemplifies the C_{HL}, representing the maximum number of forms that can be concatenated in European (*eWordFlow*) or African (*aWordFlow*) languages, according to the surface structure of each grammar. These items are subsequently transmitted as an output string to other speakers during an exchange. An exchange is defined as the transmission and receipt of an 'utterance (merged string of words)'. The quantity of forms that make up an utterance is parameterizable, for this model between one and twenty concatenated items (containing stems and affixes) are randomly generated to make up a given string. The recipient of the utterance acquires (i.e., analyzes as an input string whose units may, over time, be permanently stored in the lexicon) information from a given speaker. On analogy with the resources posited in the L2 language processing literature, the agents in the model store information as long-term in the lexicon only after a specific number of exchanges, when an item has been encountered repetitively. We do not distinguish the length of utterances that adult speakers direct to L2 adults. Furthermore, we make no allowances in the model for language acquisition based on overheard conversation or indirect input; all exchanges are agent-to-agent.

Crucially for this work, we follow the assumption that child language learners are substantively different from adult L2 learners. The claim that adults do not enjoy similar access to UG is founded on empirical support from numerous psycholinguistic accounts (Hyltenstam and Abrahamsson 2003, Hudson and Newport 1999, Hudson-Kam and Newport 2005, Ionin and Wexler 2002, among others), and creolist studies (DeGraff 1999, 2005; Lumsden 1999, and comments in Winford 2003).[15] We further assume that the lexicon provides long-term compartmentalized storage for lexical stems and inflectional affixes/markers. For adult speakers, the model represents the lexicon as a list classifying each native (L1) lexical stem and affix/marker, plus any non-native (L2) words (minimally, stems) acquired. That is, adults not exposed to two languages from birth store new L2 lexical items separately from L1 forms (Bialystok 2001), therefore L1 and L2 items are potentially differentiated within our model's adult lexicon. In light of the characterization for adults, it remains to be seen whether the outcome of the model will be affected in decisive ways. For instance, given the presumed limited availability of UG in adults, this constraint alone may sufficiently bias the adult-only model towards producing prototypical creole effects.

Chronology is an important variable which is approximated in the model. A unit of time is represented by each cycle of the computational model that elapses. The *Length of a Year* parameter is set at 12 iterations of the computer program. While these time steps are abstractions, they play a fundamental role in identifying historical language contact benchmarks over a specified period. Figures 3 and 4 illustrate monitoring of population and age dynamics over time:

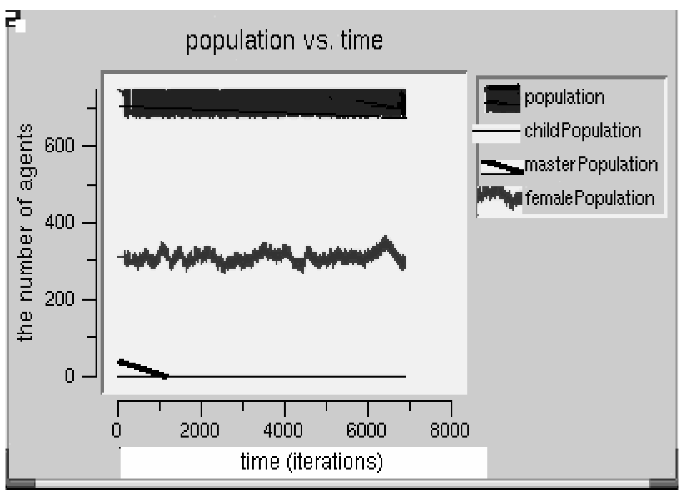

Fig. 3. Population distribution over time based on documented stages in Surinam. Graph lines, from bottom to top: Child population, European population, Female population and Total plantation population (labels in original color-coded legend in this and subsequent figures are ordered differently than actual graph lines).

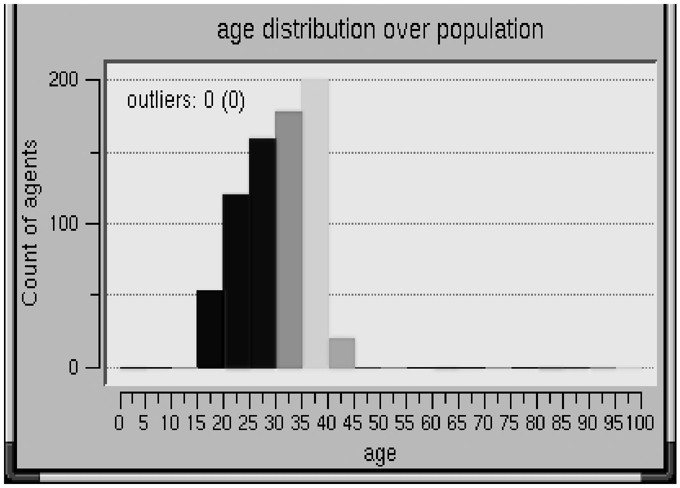

Fig. 4. Age distribution at cycle 7000 in the model, based on historical demographic data of Surinam described by Arends (1995).

Specifications of agents

Agent-level variables in SWARM endow agents with individual features and behavioral rules. Fixed attributes based on gender, racial group, age of death, etc., are designated as unique profiles for each agent. Each profile contributes to the demographic makeup of the plantation. Many states are encoded in binary (0,1) alphabets, based on specifications such as *sex*, where 0 = male, 1 = female; *dead* 0 =no, 1 = yes; *social class*, where 0= slave owner, 1 = slave; *fertile*, where 0=no, 1 = yes; and so on). Cultural identity and social status are flexible parameters which may vary over time, again in keeping with the documentation presented in conjunction with Sranan. Agents are monitored via the *slaveIndex*, which provides cultural information in the form of a 'tag' similar to Axelrod's (1997) cultural chromosome. The tags link the agent in a more fine-grained manner with agents who share certain traits that we wish to track. Adult slaves are assigned 0-4 based on their occupational roles in the plantation society. Overseers (index =1) have high occupational status among slaves, whereas house-slaves have an index of 2. Field hands and infirm slaves receive progressively lower indices.

Local Rules for Agents

Movement rules

Movement functions of SWARM provide the basis for language contact in the plantation. The society's inhabitants are dynamic, and movement through the environment allows them to engage in potential linguistic interactions with a range of individuals, under complex conditions. Agents are always located in a specific slot, identifiable by ordered pairs of x-y coordinates. Inhabitants never overlap or occupy the same position in the world. To interact, agents seek interlocutors, and thus indirectly 'compete' to move through the search space. The movement rule incorporates frequently overlooked socio-historical factors such as power and domination within a social context (cf. Siegel 2003: 190), such that agents of higher status have priority for movement over lower status agents. The rule first applies to slave owners (Europeans), then applies sequentially to overseers, house slaves, field slaves, etc. Movement is further based on the intuition that an agent interacting with a larger number of individuals will make more impact on the language contact setting. Execution of movement rules takes place when an agent moves to the closest unoccupied cell that also has neighboring agents. A neighbor is identified as the individual in the slot situated adjacent to the agent. The number of neighbors for potential exchanges is parameterizable in the simulation. The model currently allows for a maximum of four surrounding neighbors at the north, south, east, and west slots, as based on the formal conception of von Neumann neighborhoods. Since access in the present model is restricted to linguistic information from surrounding neighbors of the appropriate status, agents are typically limited to exchanges with one acceptable neighbor per learning cycle.[16]

The application of this particular movement rule may be grounded on certain contentious assumptions. First, our criteria imply that physical distance is directly related to social interaction. That is, the rule sets the stage for interaction only between bordering neighbors, as we view adjacency as a logical, though simplistic, prerequisite for linguistic encounters. Neighbors in the model do not blindly interact; rather, the social factors that constrain contact will be discussed shortly. Secondly, to the extent that identification of the "closest unoccupied cell" is a dynamical process in the model, an agent may randomly cover both large and small distances of the plantation. With each movement, the agent potentially encounters a broad diversity of new neighbors whose distribution in the space may not necessarily be predictable in a historical sense. Our hypothesis is that while initial generations of inhabitants in the model operate under 'broader' conditions, successive generations will not be as diverse, in ethnic, sociocultural or linguistic terms, due to the nature of later interactions. This projected development parallels real-world social contexts in various Atlantic language contact settings (Arends 1995, Chaudenson 1992, McWhorter 1998).

Agent social interactions

Linguistic exchange, as constrained by cognitive resources and social factors, is the mode for acquiring and processing the linguistic input to which agents are exposed. Due to the range of possible linguistic encounters, the speaker may form novel linguistic patterns that she subsequently transmits to others; alternatively, she may transmit existing structures. The dynamic nature of the CAS is such that neither the selections made by the speakers, nor the overall results are necessarily predictable. In short, the agent's developing I-language can drastically change based on the outcomes of her random exchanges.[17] The micro-grammar(s) formed may eventually be adopted globally as E-languages across the total population, but this macro-grammar only emerges via multiple, autonomous interactions of individual agents. In the present model, language learning occurs based on a loop of simple instructions executed sequentially.

In the model, adults (agents age 12 and older) are assigned their specific agent profiles and distributed into the artificial society. Contact occurs through the movement rule. Regardless of adjacency, the neighbors must be 'socially eligible' for linguistic exchange. The algorithm is implemented in the following manner: during the initial encounter, suppose that agent1 transmits an utterance to her adult neighbor, agent2. If during the interaction with agent2, an item in agent1's utterance is not found in the current lexicon of this neighbor, agent2 will then add the new element to her working memory, contingent on the social and linguistic constraints outlined throughout this section. If agent2 then receives an utterance from adult agent3 and encounters the new lexical item again, agent2 will add this new item to her lexicon (long-term memory). Thus, another critical assumption in this model is that statistical frequency plays a role in the language learning process (Saffran et al. 1996, Hudson-Kam and Newport 2005).[18] Logically, agents may output a larger quantity of their L1 items to other speakers, if the adult L1 lexicon (permanent storage) is relatively larger than the L2 lexicon. Beyond the respective African- and European-language *Wordflow* surface structure parameters, we do not intentionally control the length of utterances generated. That is, per Ochs and Schieffelin (1994), no compensations are made in the model for L1 "foreigner talk" or simplified speech directed at L2 learning agents. The exchanges occur in parallel for various agents throughout the plantation. As the first cycle of the model is completed, the algorithm can be repeated for any number of iterations.

EXPERIMENT

Methodology

The objective is to now integrate the various components into the SWARM program and to observe whether linguistic structures develop. It is vital that the reader understand that while there are desired objectives, they have not been designed into the system a priori. That is, the possible outcomes cannot be predicted, due to the dynamic nature of the rules and the emergent CAS behaviors at each point in the model. Based our assumptions underlying prototypical creole effects (e.g., SVO word order, European superstrate with African language substrates), this particular experiment may provide optimal conditions for the emergence of adult speakers with an L2 knowledge state consisting of European lexical inventories while maintaining (reduced) L1 inflectional markers resembling the African-language paradigms.

RESULTS

The general outcome of the experiment is averaged from numerous trials, each spanning 7000 iterations (approximately 580 'years').

Testing the 'Imperfect L2 Acquisition' hypothesis

Contrary to the 'imperfect L2 acquisition' hypothesis, our findings indicate that neither a basilect nor acrolect variety of a creole materializes such that all creole effects are present over time. However, as will be discussed below, a new L2 form spontaneously surfaces as the E-language in the plantation society.

Figures 5 and 6 represent the micro-level view, the I-language of an average adult inhabitant in the population. These are 'snapshots' of the average lexicon (the average quantity of words and affixes) at any given point in the simulation, where the average speaker in this setting is statistically an adult male field slave. Figure 5 illustrates the average composite of European- and African-language words (and lexical stems) across time.[19] Lines that are jagged and thick in appearance indicate a noisy yet stable pattern of activity within a particular language group. After the initial 1-2 generations of individuals, the average adult speaker possesses a small amount of L2 lexical knowledge. This state is represented nearly exclusively by African languages, with little influence from European elements, where the resulting sequence is: Fon, Kikongo, Twi, and other African-words, respectively. The category of *'other African-words'* are representative of minority African languages. This class persists in the average speaker's L2 lexicon with typically fewer than 100 words. The average number of European words steadily declines from approximately 50 words/stems in an average lifetime (e.g., after 42 years or t_0 to t_{500} iterations).

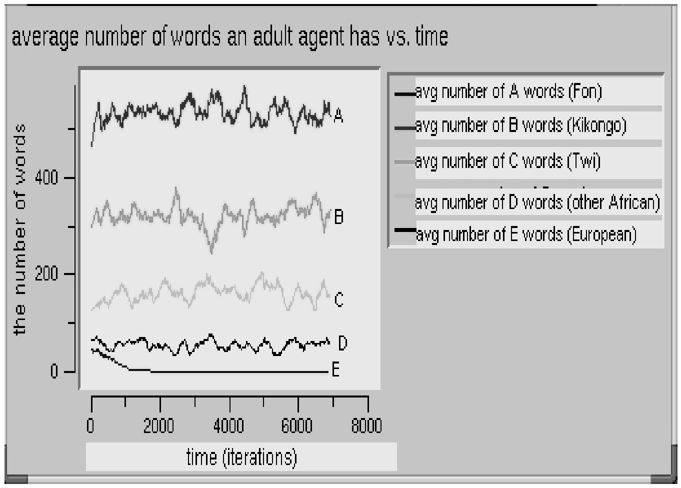

Fig. 5. European- and African-language words in average adult's lexicon across time. Fon (*"average number of A-words")* has a high demographic status among African-languages. Category *'other African-words'* (second line from bottom) represents minority African languages. Number of European words (bottom line) declines over time in average adult lexicon.

Figure 6 highlights the average adult's store of inflectional (grammatical) morphemes and TMA markers. The topmost line signals the L1 inventory of African-languages markers/particles, shown initially to be slightly less than 100 items across all African languages. There is evidence that the adult has access to inflectional morphemes in that after the first 500-1000 cycles, the knowledge of African-based markers reaches its maximum, signaling the adult acquisition of L2 of morphological affixes. This value then remains constant at 100 markers. In the same time span, the number of European inflectional affixes in the I-language decreases to zero. The thin, straight lines indicate sparse learning activity.

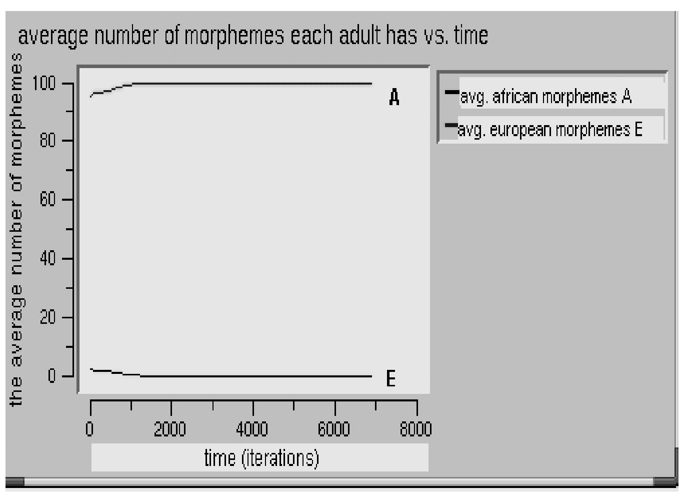

Fig. 6. Average adult's store of inflectional markers. Topmost line signals L2 inventory of African-languages markers, shown initially to be slightly less than 100 items across all African languages. Adult acquires inflectional information for 500-1000 cycles, when knowledge of African-based markers reaches its maximum. Number of European (English) L2 inflectional affixes acquired (lower line) decreases to zero for average adult.

In preliminary conclusion, the average adult possesses knowledge of a variety of African-language lexical items which can be merged with the African-languages inflectional markers of the speaker's lexicon to produce words and utterances. The resulting structures may correspond to a type of African-internal pidgin/creole, especially given the quantity of lexical items available in an average adult's grammar. However, even in this respect there does not appear to be a significant language shift either in terms of lexical or inflectional aspects of the lexicon from one primary African language to another. We will return to discussion of these points shortly.

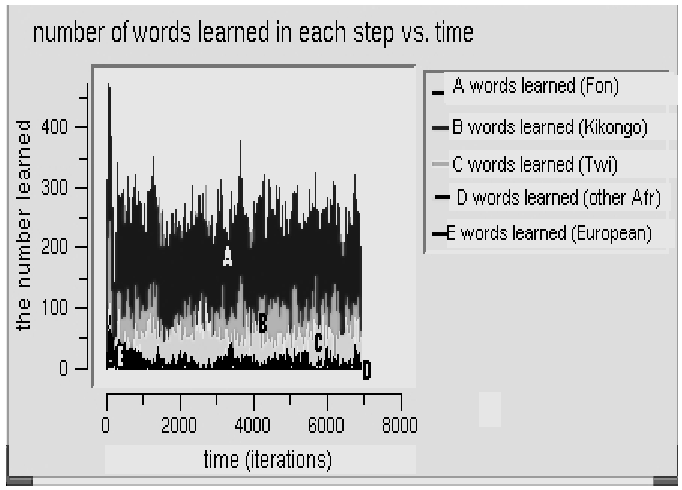

Fig. 7. Lexical items acquired across total adult population. In initial time steps, Fon items (A-words and top range of graph) are acquired with highest frequency. Collective L2 lexicon emerging is small, yet all languages in contact setting initially contribute. European words/stems (bottom left corner of graph only) emerge early within adult-only population, but disappear beginning in cycle 1500.

Figures 7 and 8 represent E-language within the adult L2 context, signaling structures acquired across the general population. These graphs reflect the input to which L2 adults in the environment would be potentially exposed at any given time. Figure 7 shows the quantities of lexical items acquired across the total population. Although small amounts of items are acquired on a population-wide basis, the graph is extremely rugged, demonstrating the dynamic nature of the learning taking place. In the initial time steps, Fon is acquired at the highest rate across the population. This global rate is reported at 250-350 words learned per cycle in this experiment, as compared with the average individual (Figure 5) with 400-500 lexical items in Fon.[20] The emergent L2 lexicon is smaller, yet all languages in the contact setting initially contribute, including Kikongo, Twi, European words, and words of minority African-languages, respectively. After 500 time steps, Fon and Kikongo words/stems are learned at nearly equivalent rates by the general population. At t_{1000}, the frequency of Fon words acquired shows minimal gains, then drops substantially between t_{1500} and t_{3000} while Kikongo remains stable at 300 words/stems across all speakers. Fon eventually regains its dominant presence (likely owing to the periodical influx of slaves), maintaining approximately 350 words learned in the plantation population for the remainder of the simulation. European words/stems emerge early within the population, but have disappeared as early as cycle 1500. Words in Twi and the class of "other African-languages" are for the most part stable during the simulation posting 100 words and 50 words learned in the population, respectively, at each time step.

Figure 8 charts the population-wide acquisition of English and African language inflectional morphology over time. In reality there are two thin and rigid lines which are superimposed, however they visually appear in the graph as a single line given their equivalent values designating absence of activity. This graph indicates what may be considered predictable in the L2 acquisition of inflectional morphology for pidgin grammars: there is no emergence of new African or European inflectional items into the E-language of the plantation. We elaborate upon these outcomes in the following section.

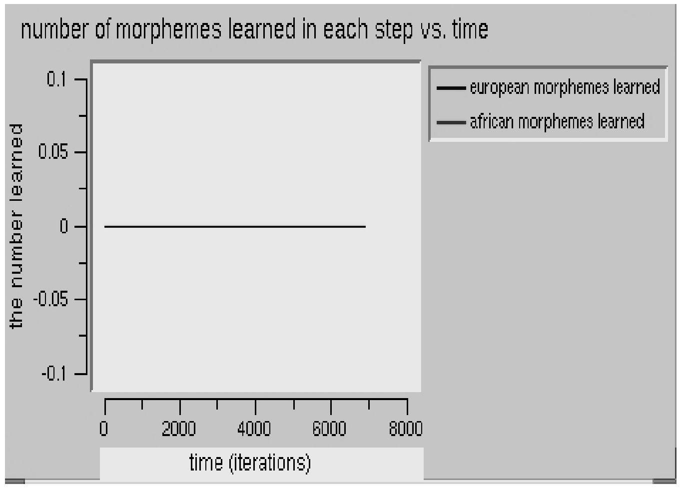

Fig. 8. Number of English and African language inflectional morphemes acquired by the total adult population over time. Both lines are at 0, indicating that while some morphemes may be acquired by certain individuals (as shown in Figure 5), there are no African or European (English) inflectional items that are learned through L2 acquisition processes by the entire adult population of the plantation.

DISCUSSION

Comparing I-language to E-language results, the average individual L2 lexicon is relatively larger and more ‘complex (i.e., containing more lexical items and inflections)’ than that of the general population. For several reasons the I-language falls considerably short of being an emergent creole: a) the number of L2 words stored as I-language on average is scant; b) no pronounced restructuring in the general pattern of lexical storage arises; and c) feature expansion does not occur. As noted above, we preliminarily interpret the resulting I-language structures as an African-based pidgin, based on the reduced quantity of L2 lexical items present. However, the availability of L1 inflection may qualify more as a type of stable expanded pidgin or ‘foreigner talk’ capacity that has emerged as the ‘L2’ grammar of the average plantation inhabitant (male field slave).

The E-language exhibits prototypical pidgin characteristics, since the lexical inventory is quite limited and concurrently no inflection exists. The lexical items stored consist of the common subset of shared items across the population. While this pidgin—as most pidgins—emerged abruptly (within 24 cycles or 2 ‘years’), it is quite stable. The scenario lends indirect support to related notions of McWhorter (1998, 2005) in the claim of a pre-existing West African Pidgin prior to the emergence of Sranan, although in the current case the pidgin emerges with the plantation setting as the initial contact point. All told, an interesting dynamic unfolds between the relatively ‘sophisticated’ internal L2 knowledge of the average speaker which includes a scant acquisition of L2 inflectional morphemes and the pared down external L2 repertoire arising in the overall population. Of particular note is the rapid diffusion and stability of the pidgin variety throughout the general population.

Some final issues merit attention: first, the intent to remain faithful to as many demographic points as possible and to endow adult learners with realistic resources does ultimately lead to an invariant bias in the model. It is tempting to argue that populations of elite house slaves and overseers would acquire a (higher) portion of European language features, due to their necessary interactions directly with the slave owners and the high social value of that they would attain for acquiring (aspects of) the L2. Repeatedly, the absence of genetic reproduction in the model produced a situation of early ‘extinction’ for European inhabitants. Based on the historical records, new influxes of Europeans were not periodically introduced (Arends 1995) as occurred for the continually replenished African population. This general paucity of Europeans and diminishing contact with them over time, coupled with stable and growing African groups, is precisely the intuitive conclusion that creolist scholars advance for the emergence of Sranan, Haitian Creole, and other historical plantation colonies. The present model shows that these conditions may have more naturally resulted in the widespread maintenance of an L2 African language variety across the society for an extended period of time.

Secondly, we must be cautious with interpretations of this model that attempt to link the lack of L2 mastery or creole formation with the fact that no child agents were included. Our study specifically examines the notion of a population of adult language learners as the most plausible originators of a creole variety, in keeping with the L2 adult creole genesis hypothesis advanced in the literature. However, we submit that the number of children and the interactions necessary for their presence to have linguistic significance are open questions that can be effectively addressed in part by computational modeling. There are some principled estimates of the numbers of children populating the plantations at the time of Sranan's emergence, even while historical records remain scanty. Preliminarily, computational models in Satterfield (2001, 2005a) reconstruct the situation in which children are 'rare' and have limited social interactions throughout the plantation setting, based on a simplification of Arends' (1995) projections. Satterfield's studies illustrate that when children between the ages of 5-11 years old make up between 10%-15% of the total population, plantation outcomes towards creole formation are significantly increased. Unlike the Language Bioprogram Hypothesis (Bickerton 1984), the computational models do not demonstrate that children (without intervention from adults) play a central role in (Sranan) creole formation, nor do the simulations uphold any claim that children must have existed in large numbers in the population. Moreover, Satterfield's (2001, 2005a) computational models suggest that the children emerging with 'prototypical creole effects' were likely to exhibit bilingual linguistic knowledge, but only when allowed broad contact with adult speakers in the plantation setting. Following Sebba (1997:179) and Roberts (2000), and as noted in Becker and Veenstra (2003), child bilingualism may well be a necessary precursor to creole formation.

CONCLUSION

In terms of our initial objectives, the aim of this paper was straightforward: we examined the standard "imperfect L2" theory of creole formation to determine whether its central constructs could be faithfully applied to model a (relatively) well-documented historical setting. We also illustrated that the psycholinguistic attributes and capacities of adult L2 learners as implemented in the model are in line with the L2 creolist proponents view (although the computational parameters are by necessity more explicitly outlined than most standard creolist proposals given the requirements of computer programming algorithms). Overall, this study has demonstrated that it is possible to reconstruct historical contexts for examining cognitive and cultural issues in light of language emergence and change. Large-scale effects were produced in the plantation domain as populations of agents interacted and adapted locally in various ways within a CAS environment. Based on micro-specifications with regard to agents, the environment, and rules of behavior in the model, innovative macro-structures and collective behaviors were generated in the system. Thus, the emergent property of the CAS—in this case, of growing linguistic structures in the computer—is clearly demonstrated in the present study.

As regards creole formation, the findings of the current computational model have been found to be inconsistent with the 'imperfect L2' hypothesis.[21] 'Prototypical creole' effects mirroring Sranan structures were not evidenced in the present study's I-language or E-language results for adult L2 speakers. Adults created an incipient stable pidgin which continued with each successive generation of L2 speakers; however, expansion of the lexicon or radical changes in the structures did not occur in this adult-only context.

While the fact that creoles did not emerge in the adult L2 context cannot be directly attributed to the absence of children in the population based on this single experiment, we suspect that the childless aspect may be linguistically relevant, especially when viewed in conjunction with several other social factors: a) the increasingly restrictive and hierarchical nature of plantation society rendered improbable the need for most adults to engage extensively in prolonged crosslinguistic contact, whereas young children were typically allowed to circulate relatively freely (Arends 1995); b) the wave of African-born slaves regularly introduced into the environment permitted established adult slaves to retain an L1 base for communication; and c) sufficient prestige/social currency may actually not have been generated for the average adult substrate speaker to be inclined to acquire more than a few lexical items of the L2 target.

Possible criticisms of the current investigation could include the notion that such computational models are path-dependent, in that the results are shaped by the precise initial conditions chosen. However, this evaluation does not easily hold for experiments representing a CAS approach. As demonstrated, with the CAS it is not trivial, and sometimes it is impossible to determine what behavior a CAS will generate, even with a relatively simple CAS. Moreover, while we quite tentatively interpret the negative results (e.g., that a creole language did not emerge, in contrast to real world outcomes of Sranan) of this single experiment as an indication that certain presumptions of 'imperfect L2' are flawed, modifications which do not adhere so closely to this particular 'imperfect L2' theory could be tested in subsequent models and could conceivably yield different results.

Motivated by theoretical and practical concerns, such modifications might include phonological and semantic features that contribute to the selection/exclusion of specific grammatical and lexical elements over others. It would also be ideal to adapt the model to examine other language contact scenarios. Lastly, demographic factors must be fine-tuned to include more facts of African and European populations and to pinpoint those 'critical mass' conditions necessary for triggering individual and population-wide creole emergence over time.

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[1] For a critical overview of the Language Bioprogram Hypothesis, consult Veenstra (in press).

[2] There is a trend in the gradualist-oriented theories to argue against an abrupt model in the formation of Caribbean plantation creoles, even though these were not previously assumed to have arisen from stable pidgins (Singler 1996, among others).

[3] Due to scope constraints, abrupt creole formation theories based on adult L2 acquisition (e.g., Relexification Hypothesis (Lefebvre 1993) and Crosslinguistic Compromise/Negotiation Hypothesis (Thomason and Kaufman 1988, Thomason 2001)) will not be covered in detail in the current study. Also, consult for example, McWhorter (1998, 2000) for counter-evidence and commentaries against the gradualist hypothesis.

[4] Also see Long (1990), O'Grady (1997, 2003) and Bhatia and Ritchie (1999) for in-depth overviews on maturational effects in language acquisition.

[5] These studies have been further informed by data in Siegel (1987).

[6] Interlinear glosses are my own.

[7] As Mülhäusler (1997) aptly notes, the nature and actual amount of mixing found in creoles is often underestimated (see note 12). So while the Sranan lexicon is primarily English-based, Portuguese, and a plethora of Dutch words also contribute to the vocabulary. A number of lexical items are also taken from Javanese and America Indian.

[8] The admittedly simplified "prototypical creole" characterization adopted for the present study is based on a general description found across the creolist literature; however, we duly acknowledge Mühlhäusler (1997:5) among others, who note that the classification/definition of pidgins (and creoles) based on a principal lexifier language is to be avoided, since a) the highly mixed nature of pidgin (and later, creole) lexicons is often overlooked in the literature; and b) it has never been established why the lexicon should be considered as the base of the language, rather than the semantic-syntactic system.

[9] As Arends (1995: 264) states, very little is known about birthplace and rate of nativization of slave populations during the periods when Sranan was being formed.

[10] If such strict linguistic divisions were in place, they would have easily been instantiated by the social practice of *seasoning*; entrusting older, acculturated slaves in a plantation to acquaint recently arrived slaves with life in the colony, in a shared African language, as outlined in Valdman (2000:156).

[11] Valdman (2000:155) points out from historical records that plantation owners were instructed by colonial officials to separate slaves from the same ethnic group in order to avoid uprisings. However, this policy was not strictly enforced by plantation managers, since laborers who worked in teams in the sugar mills or in the cultivation of crops needed to be able to communicate efficiently. It was likely that work forces consisted of homogeneous slave groups from the same "nation."

[12] We limit the discussion to a basic outline of the components that will be represented in the current model. The reader should consult the references listed for more detailed argumentation motivating these concepts.

[13] Due to space limitations, discussion of derivational morphology rules are not treated in this paper.

[14] The model presupposes a simplified language contact scenario that is activated only in this new plantation environment. Each adult brings as part of his linguistic history only one developed L1 and no other lexical influences to the language contact setting; however only the developing L2 knowledge will be tracked, as opposed to both L1 and L2.

[15] Where UG may include the following: larger working memory, faster processing rates, more inhibitory mechanisms, etc. per Johnson and Newport 1991, Strozer 1994, Miyake and Shah 1999), and a higher capacity for acquisition of L2 inflectional morphology (Hudson-Kam and Newport 2005, Lardiere 2000, etc.).

[16] The “world” landscape implemented here is actually toroidal; for instance, the right edge of the graphic wraps around to the left edge. Agents situated on the periphery thus can have the same number of neighbors as agents more centrally located.

[17] Importantly, agents do not intentionally move in order to have a complete view of all the other agents, nor can they consciously move to selectively develop particular languages. Likewise, no single agent completely controls all possible movement behaviors of others.

[18] The number of encounters necessary for addition to the lexicon is a parameterizable value. In the current simulation two instances of exposures were employed, due to the small number of neighbors involved.

[19] Due to space considerations, extensive data details in *Wordflow* are not presented in this paper. Nevertheless, the strings produced by the agents were consistently of SVO word order.

[20] We juxtapose this situation with an average of 1250 items per time step that emerged in a related creole genesis model in which the L2 adults interact with a limited number of children as well (Satterfield 2005a).

[21] As an anonymous reviewer rightly observes, “There's a problem with any simulation result showing a negative result to argue against a theory. If a particular result fails to emerge in the simulation it's hard to know if this is a failure of the theory or a failure of the translation of the theory into the model.…it is a tricky aspect of modelling in general…Certainly, the most useful thing that can be done is to consider modifications to the theory that could be translated into the model to give positive results.”