Age of acquisition predicts rate of lexical evolution

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Abstract

The processes taking place during language acquisition are proposed to be adaptive influences that contribute to language evolution. However, evidence demonstrating the link between language learning and language evolution is, at best, indirect, constituting studies of laboratory-based artificial language processing or computational simulations of diachronic change. In the current study, a direct link between acquisition and evolution is established, showing that for two hundred fundamental vocabulary items, the age at which words are acquired is a predictor of the rate at which they have changed in studies of language evolution. Early-acquired words are more salient and easier to process than late-acquired words, and these early-acquired words are also more stably represented within the community's language. Analysing the properties of these early-acquired words potentially provides insight into the origins of communication, highlighting features of words that have been ultra-conserved in language.

Key words: language acquisition; language evolution; age of acquisition; communication origins; vocabulary structure

Age of Acquisition Predicts Rate of Lexical Evolution

1. Introduction

There is growing interest in the relation between the way in which language is acquired and the way in which it has evolved (Bickerton, 1990; MacDonald, 2013; MacNeilage & Davis, 2000; Nowak & Krakauer, 1999; Slobin, 2005). Christiansen and Chater (2008) proposed that one of the major adaptive pressures for language is that it must be acquired, and so ease of acquisition is intimately involved in language evolution. However, evidence for links between acquisition and evolution is thus far indirect, involving computational simulations (Chater, Reali, & Christiansen, 2009; Kirby, 2001; Monaghan, Christiansen, & Fitneva, 2011; Smith, 2004) or laboratory-based behavioural experiments (Kirby, Cornish, & Smith, 2008). At best, these studies can only provide convergent evidence toward language learning relating to evolving language structure (see, e.g., Rafferty, Griffiths, & Ettlinger, 2013).

Studies of language acquisition have also been hypothesised to provide insight into the nature of the origins of human communication. For instance, MacNeilage and Davis (2000) suggested that phonotactics of early productive vocabulary reflected the structure of words in proto-language: the phonological properties of words that children first produce are those that are prominent in reconstructed proto-language vocabulary. Spector and Maurer (2006) similarly claimed that the features of language spoken to children very early in their acquisition provide insight into language origins (see also Ramachandran & Hubbard, 2001). They suggested that the preponderance of sound symbolism in child-directed speech promotes language acquisition by highlighting to children that spoken words refer to objects and actions in the environment around them, thus resolving the symbol-grounding problem.

Such ideas relate to theories of imitation in speech as a source for first communicative gestures in proto-language (see Cuskley and Kirby, 2013, for review).

However, these previous accounts lack direct evidence of connections between processes of language acquisition and evolution. Yet, there is potential for establishing this link through historical linguistics studies that investigate evolution of individual words (Pagel, Atkinson, Calude, & Meade, 2013). Pagel, Atkinson, and Meade (2007) estimated the rate of evolutionary change of individual lexical items by determining how many distinct cognate forms there are for the meaning of that item across languages within a phylogenetic tree of Indo-European languages. Meanings with many distinct cognate forms indicate rapid evolutionary change, those with fewer indicate greater stability of the word's form. Pagel et al. (2007) discovered that higher frequency words are more stable than lower frequency words. Frequent occurrence seems to protect the word from replacement by an alternative form.

If language acquisition is directly implicated in language evolution, then there should be a similar relation between the rate of evolutionary change of a word and the point at which that word is acquired by the learner. Words that are acquired early in children's development demonstrate greater salience and stability of representation – early-acquired words are retrieved more quickly and accurately than later-acquired words (Juhasz, 2005). Relatedly, early-acquired words are more enduring when a speaker's language is depleted as a consequence of ageing (Hodgson & Ellis, 1998) or acquired cognitive impairments (Bradley, Davies, Parris, Su, & Weekes, 2006; Holmes, Fitch, & Ellis, 2006). Hence, early-acquired words should be less vulnerable to change than late-acquired words due to the cognitive prioritisation that such early-acquired words are afforded. Similarly to the observed effects of frequency of usage for conservation of a word's form, the individual's early acquisition of a word should result in greater stability in language evolution.

In order to assess whether language acquisition does relate to language evolution, the age at which vocabulary items are acquired was tested as a predictor of the rate of evolutionary change of words.

2. Material and method

The database of words comprised 200 words in English that are fundamental terms in most language vocabularies (Swadesh, 1952), taken from the Indo-European database (Dyen, Kruskal, & Black, 1992). Rate of lexical change was derived from the number of distinct cognate forms across 87 different languages, where words with a greater number of distinct forms indicating a higher rate of change for that lexical item (see Pagel et al., 2007, for more details of the model used to derive the rate of change estimates for each lexical item). Word-frequency was taken from the British National Corpus (Leech, Rayson, & Williams, 2001), calculated from a corpus of 100 million word usages in British English. The database of words, with their rate of lexical change values, was exactly that used by Pagel et al. (2007).

Age-of-acquisition (AoA) values for the words were taken from Kuperman, Stadthagen-Gonzalez, and Brysbaert (2012). These values were constructed from subjective judgments of AoA for more than 30,000 words, and were highly correlated with other measures of AoA on smaller data sets (e.g., Stadthagen & Davies, 2006). The word *ye* was not included in the database, and so the AoA rating for *you* was used in its place (the inclusion of the *ye* form in the original lists was to record distinctions in number for pronouns across languages).

In order to isolate the effect of AoA from other related properties of the word, it is also important to include in any analysis measures of words' similarity to other words and word length (Kuperman et al., 2012). This is because early-acquired words tend to be shorter and more similar to other words than later-acquired words. In the current analyses, a measure of length in phonemes and phoneme neighbourhood was included, defined as the number of other words that differ by a single phoneme from the current word (Vitevitch, 2002). Similarly, early-acquired words tend to be higher frequency, and so the relative contributions of AoA and frequency must be determined in an analysis that includes all these variables. Early-acquired words also tend to be higher in concreteness, and so concreteness ratings (Brysbaert, Warriner, & Kuperman, in press) were also gathered for all but one of the words (*louse* did not appear in the concreteness database, and, as with the AoA values, the concreteness rating for *you* was used for *ye*). Note that in Pagel et al.'s (2007) analysis, only grammatical category and word frequency were included, and other potentially confounded psycholinguistic properties of words were not jointly considered. The current analyses therefore provide a confirmation that the observed frequency effects in terms of rate of evolutionary change of lexical items are not due to other properties of high versus low frequency words.

Frequency measures, such as those used in Pagel et al. (2007, 2013) provide an estimate of current frequency of usage of words, but they do not acknowledge the potential role of quantity of exposure to words for an individual across their lifetime (Brysbaert & Ghyselinck, 2006). In order to determine whether contemporary frequency usage, or lifetime cumulative frequency, may be driving the effects a measure of estimated cumulative frequency was computed by multiplying the frequency of the word by the length of time the word has been known, according to AoA norms, up to the age of 18. Thus, cumulative frequency was for an 18 year old speaker. Cumulative frequency also ensures that any effect of AoA is not actually due to lifetime frequency of exposure to the word, as cumulative frequency is a consequence of AoA and frequency (Ghyselinck, Lewis, & Brysbaert, 2004).

3. Calculation

The psycholinguistic variables were entered into a hierarchical multiple regression with rate of lexical change as the dependent variable. At the first stage, Pagel et al.'s (2007) analysis of word category and log-frequency as predictors was replicated. At the second stage, concreteness, phonological length, and phonological similarity were added, and at the third stage, log-AoA was also added. The log transform was applied to AoA to control for multiple outliers that could skew the effects (Rousseeuw & Leroy, 1987). A second regression analysis was identical to the first except that log-cumulative frequency was used in place of log-frequency.

4. Results

Table 1 shows the results of the first multiple regression, with log-frequency, AoA, concreteness, and the two phonological psycholinguistic variables. The first stage replicated the results reported by Pagel et al. (2007): higher frequency words are less prone to change, though the precise values are slightly different because one word (*louse*) was omitted in the current analyses. Stage 2 demonstrated that, in addition to frequency, phonological length was a predictor of rate of lexical evolution: Longer words change more rapidly than shorter words. At stage 3, critically, AoA was also found to be a predictor of rate of lexical evolution: Early-acquired words change less quickly than late-acquired words.

At stage 3, the contribution of frequency remained significant when the other psycholinguistic variables were also included, β = -.191, t = -2.245, p = .026, indicating that potential confounds of frequency with phonological properties of the words were not driving the frequency effect. The regression results were similar if AoA was entered at Stage 1 before the other variables – frequency, AoA, and phonological length remained as significant predictors of rate of lexical change[1]. Figure 1 shows the relation between AoA and rate of lexical change.

Table 1. Hierarchical regression analysis of psycholinguistic predictors of rate of lexical evolution, including measure of contemporary frequency of usage in the first stage.

Stage	Predictor	R^2	*β*	*T*	*p*
1	Grammatical Categories	.483			
	Log-frequency		-.281	-4.127	< .001
2	Phonological length	.512	.203	3.206	.002
	Phonological similarity		.107	1.743	.083
	Concreteness		-.097	-1.058	.291
3	Log-AoA	.524	.129	2.181	.030

Table 2 reports the results of the second multiple regression, with log-cumulative frequency entered at Stage 1. The results are similar to those of the first analysis – AoA was

[1] The results were similar for AoA when the analyses were repeated but with Zipf SUBTLEX-UK frequency (van Heuven, Mandera, Keuleers, & Brysbaert, 2014) used in place of BNC frequency, which provides a better reflection of spoken English usage. In the final model including all psycholinguistic variables, Zipf SUBTLEX-UK β = -.123, t = -1.522, p = .130, log-AoA β = .144, t = 2.424, p = .016. The results were also similar when rank order of AoA (Kuperman et al., 2012) was used in place of log-AoA: In the final model, Zipf SUBTLEX-UK frequency β = -.213, t = -2.086, p = .038, rank-AoA β = .176, t = 2.415, p = .017.

still a significant contributor to predicting rate of lexical evolution when either cumulative frequency or contemporary frequency of word usage were included in the regression.

Table 2. Hierarchical regression analysis of psycholinguistic predictors of rate of lexical evolution, with cumulative frequency as a predictor.

Stage	Predictor	R^2	β	T	p
1	Grammatical Categories	.486			
	Log-cumulative-frequency		-.286	-4.257	< .001
2	Phonological length	.514	.201	3.187	.002
	Phonological similarity		.108	1.759	.080
	Concreteness		-.091	-1.013	.312
3	Log-AoA	.524	.120	1.977	.049

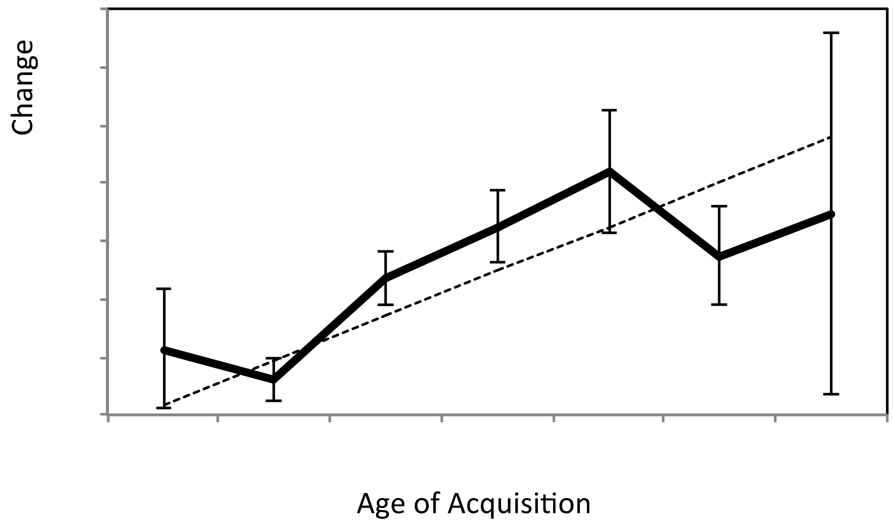

Figure 1. Relation between AoA and rate of lexical change. Error bars show ±1 standard error of the mean. Dashed line indicates the regression. Note that only 3 words have AoA ≥ 8, resulting in a large standard error.

5. Discussion

The relation found between AoA and the extent to which word forms are conserved or changed demonstrates a link between processes associated with acquisition and processes associated with evolutionary change in natural language. Previous studies have either proposed a theoretical relationship between learning and evolution (Christiansen & Chater, 2008), modelled the relationship (e.g., Chater et al., 2009; Kirby, 2001; Smith, 2004), or provided behavioural data on learnability of natural language properties using artificial language learning studies (e.g., Kirby et al., 2008; Monaghan et al, 2011). The prediction of rate of lexical evolution by AoA supports claims that language learning is vital to understanding the origins of communication (Christiansen & Chater, 2008; MacNeilage & Davis, 2000).

The properties of early-acquired words seem to preserve them from evolutionary change. Thus, importantly, it is individual speakers' history of learning, in addition to the contemporary frequency of usage by the community (Pagel et al., 2007), that predicts stability of the word form. Pagel et al. (2007) suggested that frequency of usage relating to rate of change was due to conformity of speakers aligning their language to avoid misinterpretation for words that were often used in discourse (Boyd & Richerson, 1985). However, the AoA effect cannot be explained in similar terms, as the history of learning of the individual is not directly influencing communicative exchange. Hence, language acquisition has to be taken into consideration in order to fully understand processes of language evolution. The stability of early-acquired words is likely due instead to the representational salience of early-acquired words (Juhasz, 2005) rather than to pressures from potential misinterpretations in contemporary language usage.

There are two theories in the AoA literature concerning the mechanisms underlying the processing priority of early-acquired words. First, AoA effects may be a consequence of the incremental construction of semantic representations, whereby later acquired words are incorporated into a representation already containing early-acquired words (Brysbaert & Ghyselinck, 2006). From this perspective, early-acquired words have a processing priority because they have richer, more embedded semantic representations than later-acquired words (Steyvers & Tenenbaum, 2005). An alternative explanation is that the AoA effect may be due to changes in the plasticity of the cognitive system that incrementally learns mappings between spoken forms and the meaning of words (Ellis & Lambon Ralph, 2000). For learning early-acquired words, there is greater plasticity in the system, because the mappings are unconstrained by previous learning. However, for learning later words, the new mappings must be accommodated around pre-existing mappings that have already been acquired, and these later mappings are then more vulnerable to change (Monaghan & Ellis, 2010). In either theoretical model, the lower rate of lexical exchange for early-acquired words would then be due to the greater change required to the system as a whole to replace an existing form-meaning mapping with a different form of the word.

The regression analyses in the current study also demonstrated that phonological length was a predictor of rate of lexical change. The phonological effects were primarily included to ensure that the effects of frequency and AoA were not due to some other confounded property of the words' structure. Yet, the effect of word length may suggest that longer, more complex, word forms are more vulnerable to replacement. Hence, early-acquired words that are shorter and have high-frequency of usage are most likely to be preserved in the vocabulary. Though the effect of AoA is small, it is worth noting that it is similar in size to that of frequency, even after frequency has been accounted for in the analyses of the AoA effect. Furthermore, the robustness of the effect to alternative measures of frequency and alternative treatments of the AoA variable, suggest that the results are not an instance of a type 2 error. However, testing the effects across additional languages would increase further the confidence that AoA is a language universal in terms of stabilising lexical forms in individual languages.

Another issue unresolved by the current analyses is whether stability of lexical forms is due to additional confounded properties of words that also result in their early acquisition: Perhaps these are words that are so vital for communication that communities of speakers cannot afford them to be misinterpreted. This is a possibility consistent with the results, though the Swadesh lists are composed so as to only contain words that are assumed to be fundamental across language communities, each with substantial potential cost to misinterpretation. Furthermore, it might be anticipated that concreteness would have an effect in terms of importance or salience of a word in communication – early-acquired words are higher in concreteness – and yet concreteness was not found to be a significant predictor of rate of lexical change. Partialling out the effect of concreteness did not diminish the contribution of AoA as a predictor of stability of word forms.

The role of language learning in language evolution has become a somewhat controversial topic primarily because language change appears to be driven more as a consequence of innovation in adolescent or adult speakers of the language rather than adjustments to the language associated with propagation during acquisition (Joseph, 1992; Slobin, 2005). The analyses presented here provide an interesting alternative perspective on these accounts of language change, addressing Croft's (2000) desideratum that theoreticians must provide mechanisms by which languages remain the same as well as determining the processes that drive change. Psycholinguistic analyses of lexical items that vary in rate of change provide a means by which mechanisms for stability and change can be predicted by language processing models. The current analyses demonstrate that early language learning contributes to this stability, rather than being a contributor to change, which is consistent with views about the importance of learning for language evolution (Christiansen & Chater, 2008), but contradicts accounts that propose acquisition as the point of change (see, e.g., Bickerton, 1990).

The analyses in this paper are restricted to the structure of the vocabulary. It is an intriguing issue as to whether other aspects of language structure, such as morphology or syntax, also demonstrate an AoA effect. There is some suggestion that psycholinguistic variables may be predictive of stability and change of morphological forms. For instance, Bybee and Slobin (1982) tested past-tense verb forms that were over-regularised when participants were placed under time pressure to respond. Adults tended to over-regularise more low-frequency forms (e.g. producing *weeped* or *kneeled* as the past tense form of *weep* or *kneel)*, mirroring the frequency effect on stability of vocabulary items (Pagel et al., 2007). It remains a possibility that AoA is also a predictor of which morphological forms are most likely to be changed – those irregular forms that are early acquired may be less vulnerable to over-regularisation). There is also potential for scaling up analyses to diachronic change of syntactic structures according to similar properties of frequency or AoA, but this is an issue for further investigation.

Nevertheless, analysing the properties of ultra-conserved words potentially provides insight into features of language that have been present for a longer time in languages. Monaghan, Shillcock, Christiansen, and Kirby (2014) demonstrated that early-acquired words are more sound symbolic than later-acquired words, consistent with views that the origins of language emerge from natural cross-modal relations between form and meaning (Spector & Maurer, 2009; Ramachandran & Hubbard, 2001). Sound symbolism in the early-acquired vocabulary may thus reflect the vestigial traces of iconicity that once constituted the very first uses of speech to indicate meaning.

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