Implicit learning as a mechanism of language change

FRANKLIN CHANG

Introduction

In their contribution "Priming and unidirectional language change", Rosenbach and Jaeger suggest that psycholinguistics may provide useful insights for historical linguistics and that a greater integration of these two research domains is needed. I would like to contribute to their project by pointing out work in psycholinguistics that might be particularly useful for researchers who are studying language change. Then I will discuss the question of whether priming mechanisms can contribute to our understanding of unidirectional change in grammaticalization.

Language change and Implicit Learning

For a language to change, the linguistic knowledge of individual learners must change and this modified knowledge must remain stable long enough to be reproduced in others. Psychologists study how individuals are changed in response to experience. When such changes persist, it can be considered a type of learning. But unlike active conscious learning, much of the learning that humans do is unintentional and implicit, that is, outside of conscious awareness. We watch others perform activities (e.g., using a computer mouse) and through imitation and trial and error, we slowly learn a set of motor procedures, which we cannot describe verbally, but which allow us to perform these activities. Language learning also seems to involve this kind of implicit learning, because children seem to acquire language simply through exposure to language input.

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Young children implicitly learn many of the statistical features of the language input that they experience (Gomez & Gerken, 2001). Infants can learn the distributional regularities in a speech stream made up of nonsense syllables, and use these regularities to segment speech into words (Saffran, Aslin, & Newport, 1996). Infants living in an English-speaking environment can learn non-English phonotactic regularities from only a brief auditory experience and generalize them to novel syllables (Chambers, Onishi, & Fisher, 2003). Infants can also extract form-based categories based on distributional regularities and use this knowledge to infer the categories of words that they did not experience during training (Gomez & Lakusta, 2004). These studies show that children have powerful implicit learning mechanisms that allow them to find patterns in the input and to store these patterns for a sufficiently long time to permit generalization.

Traditionally, these kinds of learning processes were thought to be mainly active during first-language acquisition. But recent work has found that implicit learning takes place in adult speakers and listeners. For example, Dell, Reed, Adams, and Meyer (2000) found that they could manipulate English phonotactics over four days by having adult speakers produce sequences of syllables with non-English phonotactics (see also, Warker & Dell, 2006). Kaschak and Glenberg (2004) found that simple exposure to a sentence construction from a particular dialect of American English was enough to allow adult participants who were unfamiliar with this construction to comprehend its meaning. And, as mentioned in the target article, the selection of a syntactic structure (e.g., active or passive) in adult speakers is influenced by the structure of previously heard or produced utterances (Bock, 1986). Interestingly this phenomenon, called syntactic or structural priming, seems to persist over time and over intervening sentences (Bock, Dell, Chang, & Onishi, 2007; Bock & Griffin, 2000). Together, these phenomena suggest that various representations in the adult language system can be *tuned* by language experience. Since this tuning is long-lasting and operates outside of conscious awareness, it has been thought to be due to a kind of implicit learning.

Implicit learning seems to be a useful candidate mechanism for language change, because it provides a way that the ambient language in the environment is encoded into the language system of both children and adults, and reproduced in their utterances. Psycholinguistic tasks

that tap into implicit learning processes are then a useful means for studying language change in an experimental setting.

The Psycholinguistics of Grammaticalization

Now I will address the issue of whether psycholinguistic mechanisms can help to explain the unidirectionality of grammaticalization. Haspelmath (1999) characterizes grammaticalization as a process where lexical categories become functional categories. For example, the English word "while" was initially a noun used to refer to a period of time ("Stop by for a while"), but later came to also be a conjunction ("While I was walking, I ran into a friend"). The unidirectionality of this kind of change is revealed in the fact that it is always the lexical category (e.g., noun) that becomes the functional category (e.g., conjunction), and never the other way around.

Rosenbach and Jaeger suggest that psycholinguistic mechanisms like priming can implement grammaticalization. While some types of priming could be important in these processes, one thing that needs to be considered carefully is the duration of priming effects. Most priming effects tend to have exceedingly short durations (less than 1 second) and this makes it difficult to use these effects to model long term changes like those that are needed for language change. For example, semantic and phonological priming effects on word production operate on the order of milliseconds (Levelt, Roelofs, & Meyer, 1999). Priming of syntactic structures can also be short-lived. For example, the structural priming effect that was reported in Levelt and Kelter (1982) diminished or disappeared when additional verbal material was presented after the prime structure. These priming effects were thought to be due to residual activation from the activation and deactivation of representations during language processing. But because activation must change quickly to support the selection of different planning units, residual activation is not a good way to model language change.

In addition to these short-term priming effects, there are priming phenomena that are longer lasting. Some of the phenomena that I mentioned in the earlier section on implicit learning can be thought of as long lasting priming effects. And within the task of structural priming, both long-term

and short-term priming effects have been identified. Hartsuiker, Bernolet, Schoonbaert, Speybroeck, and Vanderelst (2008) tested structural priming involving prime-target sentence pairs with no overlap in content words between prime and target (for example, the prime sentence (1) and the target sentence (3)), and found that priming with these structures persisted over intervening filler sentences. This suggests that abstract structural priming is long-lasting.

1) The painter hands the monk a jug
2) The painter shows the monk a jug
3) The chef shows the nun a hat

But in addition, they tested primes like (2), which share the same verb with the target sentence. Previous work found that these types of primes yield a lexical boost in priming above and beyond the effect of the structure alone (Pickering & Branigan, 1998). But in Hartsuiker et al.'s study, the effect of the lexical boost diminished quickly when the prime was separated from the target by more than one filler sentence. Their results suggest that two mechanisms are at work in structural priming, a long-term priming mechanism that operates on abstract syntactic structures and a short-term priming mechanism that is lexically dependent. The long-term abstract structural priming is important for linguistic accounts of language change, because it suggests that the usage patterns of adults can also yield long-term changes in others, and this mechanism can cause a pattern to spread across the language.

To explore the mechanism behind structural priming, Chang, Dell, and Bock (2006) developed a computational model of syntax acquisition and sentence production that was able to learn English syntactic structures from pairings of word sequences and their meanings. The model used an error-based learning algorithm that was powerful enough to learn abstract internal representations, and the model developed syntactic representations that allowed it to generalize words to novel sentence positions (Chang, 2002). Given the finding that structural priming was long-lasting, Chang et al. (2006) attempted to account for structural priming by using the same error-based learning algorithm that was used for syntax acquisition to process the primes in the adult model. They found that this learning mechanism could explain a wide range of structural priming results, including the persistence of priming over intervening sentences (Bock &

Griffin, 2000). But one result that the model was unable to account for with learning was the lexical-boost effect. Therefore, Chang et al. posited that there must also be another mechanism which supported the lexical-boost effect, and this effect was not due to learning and therefore was short-lived. This hypothesis was confirmed in the Hartsuiker et al.'s experiment that was mentioned above (also see Kaschak & Borreggine, 2008). Therefore the priming phenomena can be made up of both short-term and long-term effects, but only the long-term effects are relevant for language change.

Can the model's implicit learning algorithm explain the unidirectionality of grammaticalization? I will argue that implicit learning is needed to implement language change, but that the directionality of grammaticalization will depend on the architecture of the model and the nature of the mappings that must be learned. To illustrate this, I will describe a connectionist model of language change that used the same error-based learning algorithm as the Chang et al.'s model. Hare and Elman (1995) developed a model of how verb paradigms changed from Old English to modern English. First they trained a model to map between a lexical representation (e.g., "sing" + past participle) and a morphophonological representation which encoded the Old English verb form (e.g. "sungen"). Once they had a model that had learned Old English verbs, they would train the next generation with the previous model's output as input. So, the now-trained model was no longer the child acquiring the verbs, but was instead the parent providing input to its child (a new model). After doing that for several generations with changes occurring in each generation, the resulting model had a much simpler verb paradigm, and pattern of changes in the model matched some of the historical changes in the development of modern English.

The reason that the model developed a simpler verb paradigm over time has to do with the nature of the architecture that they used. They used an architecture which had 8 hidden units for mapping between words and their morphophonology. Since the hidden layer was so small, there was pressure on the system to regularize the language, and over time, the distinctions that were less frequent or less similar to other distinctions were lost. With this architecture, changes in the complexity of the language will always move towards greater simplicity. But it is also possible to build a model with an opposite bias. By making the hidden

layer larger than the number of mappings to be learned, the hidden layer will start to record spurious correlations. If one does the same kind of training of the next generation with the output of the previous generation, this type of model might yield a more complex verb paradigm over time.

Therefore, while implicit learning could be a means of implementing language change, the directionality of language change will depend on the nature of the system that this learning takes place in. For example, the Chang, et al (2006) model was made up of two networks, one which focused on learning distributional regularities over word sequences (sequencing system) and one which learned how to map concepts to words (meaning system). In this network, grammaticalization can occur if the sequencing system picks up a spurious correlation in the word sequences that it experiences, and through a process of learning over generations like that in Hare and Elman's model, this spurious correlation becomes fixed in the language. Can this system explain the unidirectional nature of grammaticalization? For example, the word "go" has become a future tense marker "I'm going to eat" and this has been contracted to create a new word "gonna" (I'm "gonna eat"). If grammaticalization only proceeds in one direction, then "gonna" will never become free of its positional constraints and become a normal verb. Implicit learning in the model does not block degrammaticalization, but the architecture is biased against this type of change. For example, the production of "gonna" would be supported by the sequencing system, since it has a restricted syntactic distribution. For it to enter into the meaning system and become a free lexical item, it would have to be consistently associated with a particular concept and it would have to be more strongly associated with that concept than any other word. So while the movement from lexical to functional category simply involves the recording of a spurious correlation in the sequencing system, the reverse direction would require a special set of conditions that are harder to achieve in natural language.

Conclusion

Language change is influenced by individual speakers, and psycholinguistics can provide a set of tools for studying how linguistic factors can yield long-term changes in the language system. I think the most promising set

of phenomena for language change are those related to implicit learning or tuning (rather than priming, which is a very broad term that includes many short-lived phenomena). While implicit learning can help to explain language change, it does not provide the kind of linguistic constraints that are needed for explaining particular language phenomena such as grammaticalization. Instead, I argued that the architecture of language system can be used to implement particular biases in language change.

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