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Comment

Language as a human-driven complex adaptive system Comment on "Rethinking foundations of language from a multidisciplinary perspective" by T. Gong et al.

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Artificial Intelligence (AI) has been taking the world by storm. As an externalization of human intelligence, language has a close connection to AI. While in the era of AI where natural language processing witnesses great prosperity, linguists are increasingly marginalized [1]. Why is this happening?

In the history of modern linguistics, language has been deemed as a semiotic (or formal) system. This view favors the use of formal methods to examine the laws of human language more precisely from a formal perspective. Undoubtedly, it helps us to understand some formal features of human languages. However, excessive formalization may isolate language from human beings, treating it as an autonomous system, and thus linguistic analysis may become a purely formal or logic operation, neglecting the reality of language use. This research paradigm, advanced as it seems to be, is now facing challenges when explaining human communication and behaviors in the real world, probably owing to the fact it excludes human cognition and living environment from consideration. Therefore, the findings and the discoveries are rarely used in areas such as natural language processing and language learning/teaching, which are supposed to provide practical solutions to problems in real language use.

Language is a semiotic system, but it is human-driven [11], or more exactly, it is a human-driven complex adaptive system [1,5,8]. Here, "human-driven" emphasizes that the structural patterns and evolution of languages are influenced by human-related factors, including the internal ones like human physiology, psychology, cognition, etc., and the external ones like nature and society. This maybe mean that the universality of human cognition determines the universality of human language to some extent, and the cultural, natural, and social diversity may contribute to the diversity of language. Therefore, multidisciplinary efforts are probably much valuable to reexamine the foundations of language for a more comprehensive and complex description of the language system, which is exactly the central topic of the commented review [6].

In above definition, the modifier "human-driven" entails humans as the main driving force shaping a language system. Then, what does the other words in "complex adaptive system" mean? In systems science, "system" refers to the entire entity composed of its components and the relationships between them. Language, if perceived as a system, may well share properties common to all systems. Admittedly, language may function as a tool for thinking, a carrier

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of culture, and a symbol of identity, but its foremost function is probably to facilitate interpersonal communication. But for the need for effective and efficient communication, human language may not develop or even come into being. In order to achieve the common goal of optimizing communication, the components of language system work jointly on the lexical, syntactic and semantic levels, governed by the principle of least effort [12,14]. Therefore, language is a dynamic system. Those who ignore this dynamic feature may easily get confused by the transient states of language system, which evolves constantly, thus often arriving at one-sided conclusions that fail to reflect the overall picture and essential mechanism of language system. "Complex" means that the whole is greater than the sum of the parts, that is, the performance of a system is not equal to the sum of performances of its components (termed as *emergence*). In a sense, complexity is usually related to chance or probability. "Adaptive" refers to the emergence of new structures, states or functions of a system through self-organized adaptation to the changed environment. Adaptivity is an important property of a dynamic system with a set target. In sum, as a human-driven complex adaptive system, language co-evolves with humans. So, systems science provides a very important perspective for linguistic researches [12].

The shift from the view of autonomous language system to the view of complex adaptive language system is what Joan Bresnan calls a transition "from the garden to the bush" [3]. Bresnan argues that there exists an essential difference between most mainstream linguistics and the language theories designed for the real world. What she calls "the garden" is traditional linguistics. The garden linguists mainly analyze a narrow range of elicited or introspected data, just like a few delicate flowers in the garden, and form qualitative generalizations expressed in symbolic representations such as syntactic trees and prosodic structures. In contrast, linguists in "the bush" collect the "wild" data spontaneously uttered by speakers, and form quantitative generalizations based on concepts such as conditional probability and information content. When the practical tasks require us to deal with a large area of wild bushes rather than several delicate flowers in the garden, the approach previously designed for the garden is very likely to fail. As the language material is "cultivated" by the garden linguists themselves, the applicability of their "theories" is limited.

The biggest challenge in the shift "from the garden to the bush" lies in the probabilistic essence of human language. According to the philosophy of science, a research process generally involves abstract modeling in which the features of the model correspond to the observable attributes of the object of study. A theory itself does not account for actual phenomena directly. It is through the models established by the theory that we obtain the explanations for the real world. Hence, the predictive power of a theory depends on how well reality is extracted and mapped to the model. In modeling, if one essential attribute of the reality is neglected, the models constructed can hardly produce discoveries capable of wide application. *Probability* is an indispensable property in a human language system [2], which is hard to capture via dichotomous concepts or introspection featuring in the garden linguistics. This may be one of the reasons why the era of AI is getting far away from the mainstream linguists.

Language research, in both theory and practice, has shown in recent decades that the new era calls for new changes. First, in terms of the object of study, more attention needs to be paid to the authentic language material as well as the relationship between human and language system. Second, scientific methods and advanced techniques are expected to play important roles in linguistics. Third, more cross-linguistic attempts, rather than being confined to a particular language, should be made to verify and select models. It is suggested that the diversity of languages should be probed to uncover the cross-lingual universality. These three aspects are discussed by Gong and his colleagues [6] who advocate that the foundations of language be reexamined from a multidisciplinary perspective. It is noteworthy that the reexamination of the foundation should be based on the characteristics of human languages. In other words, "multidisciplinary" does not mean a blindly made hodgepodge, but a deliberate introduction of various approaches from other disciplines, with the purpose to solve linguistic problems [6,9]. For example, a complex network approach is used to study the structure and typology of human languages [4,13]; statistical and cognitive approaches are employed to explore the universal patterns of linearization of human languages and the constraints of human cognition on language structure [7,10,14]; and computer simulation is applied to shed light on human's self-adaptation mechanism in processing long sentences [15]. These studies show that the multidisciplinary approaches do contribute to better understanding of the essence of human languages, thus helping us to reconstruct the foundations of language. During the reconstruction, one need always keep in mind the vital role of authentic language material. Once separating language from language users, we may lose our way and forget the original goal of linguistics: to discover the structural patterns and evolutionary laws of human languages.

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