Journal of Neurolinguistics 49 (2019) 237–239

Contents lists available at ScienceDirect

Journal of Neurolinguistics

journal homepage: www.elsevier.com/locate/jneuroling

Emergentism in neuroscience and beyond

Karina Tachihara*, Adele E. Goldberg

Department of Psychology, Princeton University, USA

Emergentism refers to the idea that unique, complex phenomena can be explained by the development of more basic processes that interact in dynamic ways with each other and the environment. An alternative, "essentialist" type of explanation generally appeals to one or more factors that are unique to the complex phenomenon itself. Hernandez et al. (in press) argue that the emergentist perspective provides better explanations for many findings in neuroscience, and we agree. The perspective is appealing because it makes use of independently validated processes, thereby requiring less stipulation; the perspective also offers insight into how complex phenomena develop through ontogeny and how they can be influenced by changes in the environment.

Emergentist explanations have become the norm in many fields. Within genetics, systems biology recognizes that most phenotypes are influenced by multiple interacting factors that include subtle environmental effects rather than resulting directly from one or more genes (Karmiloff-Smith, 2006; Lander & Schork, 1994). Likewise, since the middle of the twentieth century, evolutionary biologists have recognized that species consist of populations of individuals closely related to one another in a variety of complex ways (Mayr, 1975), rather than consisting of individuals that all share some species-unique abstract "essence." Physicists have long recognized that an emergentist perspective is required for explanations at every level, including the properties of combinations of electrons, combinations of atoms, and combinations of crystals (Anderson, 1972).

Hernandez et al. offer the case of face perception as a parade example of an emergent phenomenon in neuroscience, although it is far from the most obvious candidate. Face perception would appear to be amenable to a nativist account. After all, the ability to distinguish friend from foe provides a clear evolutionary advantage. Our primate relatives demonstrate expertise in faces, and face recognition evokes activation in the same stereotypical brain area across species. Moreover, a preference for faces is evident very early in development and can be selectively impaired (developmental prosopagnosia). Yet as Hernandez et al. discuss, whether the brain has evolved in any specific way to facilitate face perception is unclear. Recent work by Livingstone, Arcaro and colleagues (Arcaro & Livingstone, 2017; Livingstone et al., 2017) argue that face-specific areas of the cortex are a result of the very general way the retinotopic map is neurally organized together with the fact that infants are interested in and focus directly on faces from early on in development. In any case it is uncontested that a *full* explanation of face perception requires the recognition of other interacting abilities and their development. For example, our ability to discriminate among faces narrows as a result of experience, resulting in better discrimination among races we have had more experience with than less familiar races (Kelly et al., 2007). Moreover, we actually recognize *individuals,* not faces, and we do this despite partial occlusion, variation, and differences in perspective, just as we recognize objects, homes, and cars. These aspects of face perception likely rely on the same processes as the perception of other types of entities. We are also able to judge where someone is looking and how they might be feeling with excellent acuity in systems that are neurally distinct from the fusiform face area (Adolphs, 2002; Hoffman & Haxby, 2000). Thus, even if there does exist an attentional or representational bias toward faces in infants, it would not absolve us from explaining how face perception develops from the interaction of this bias with other recognized systems and the environment.

We wish to emphasize that if even face perception is amenable to the emergentist perspective, then surely human language—the other case that Hernandez et al. focus on—should be expected to yield to emergentist explanation. While some have assumed that our linguistic ability spontaneously arose *de novo* in humans (Chomsky, 1965), the preponderance of evidence runs counter to that perspective. For human language to have evolved biologically, it would have had to have developed quickly, before humans dispersed across continents, and it would have to have abruptly stopped evolving after the dispersal, since all humans are capable of

* Corresponding author. Department of Psychology, Princeton University, Princeton, NJ 08540, USA.
E-mail address: tachihara@princeton.edu (K. Tachihara).

https://doi.org/10.1016/j.jneuroling.2018.04.009
Received 2 February 2018; Received in revised form 23 April 2018; Accepted 23 April 2018
Available online 17 May 2018
0911-6044/

learning any human language (Christiansen & Chater, 2008). Moreover, if human language were the result of a unique biological development, it would raise the question of why it is that human languages display greater diversity than the communication systems of any other species (Everett, 2009; Haspelmath, 2008; Tomasello, 2003). There appear to be no populations that are developmentally selectively impaired (or spared) in grammatical ability alone (Donnai & Karmiloff-Smith, 2000; Leonard, 2014). Finally, while there may be a network of brain areas that are somewhat specialized for language in the adult brain (Blank, Kanwisher, & Fedorenko, 2014; Fedorenko, Behr, & Kanwisher, 2011), localization is consistent with the emergentist perspective, as it is expected to occur when particular brain areas combine to serve a complex purpose efficiently (see Hernandez et al.).

Languages appear to emerge within communities on the basis of a suite of more basic, prerequisite skills. These include human's pro-social motivation and skill (e.g., Herrmann, Call, Hernàndez-Lloreda, Hare, & Tomasello, 2007), our predilection to follow social norms (Tomasello, 2008), and our ability to learn and generalize from probabilistic input (Gómez & Gerken, 2000; Hudson Kam & Newport, 2009; Saffran, 2003; Saffran, Aslin, & Newport, 1996; Wonnacott, Newport, & Tanenhaus, 2008). The emergentist perspective predicts that languages will be constrained by communicative pressures and domain-general processes related to attention, memory, categorization, and cognitive control (e.g., Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Goldberg, 2006; Hall, Ferreira, & Mayberry, 2014). For example, there is a general functional trade-off between economy of effort and maximization of communicative power and this gives rise to many grammatical properties of language (e.g., Bybee, 2010; Futrell, Mahowald, & Gibson, 2015; Kirby, Tamariz, Cornish, & Smith, 2015; Levy, 2008; MacDonald, 2013; Traugott & Trousdale, 2013; Traugott, 2008). Moreover, grammatical constructions such as relative clauses, predicates, and passives are used and combined with other constructions in constrained ways, due to their semantics and/or discourse functions. Since children must learn the functions of each construction in order to use their language appropriately, these constraints can then be understood as emerging as by-products of learning those functions (Givón, 2001; Hopper, 1987; Kirby, 2000; Goldberg, 2006, 2016).

We endorse a shared nomenclature for work that has been done under various headings (including Neuronal Recycling, Neural Reuse, and Language as Shaped by the Brain). Since the emergentist perspective has proven useful well beyond neuroscience, perhaps an even simpler term than neuroemergentism is warranted. The *Emergentist* perspective holds promise as a way to deepen our explanations of complex phenomena in neuroscience and beyond.

References

Adolphs, R. (2002). Recognizing emotion from facial expressions. *Behavioral and Cognitive Neuroscience Reviews, 1*(1), 21–62. http://doi.org/10.1177/1534582302001001003.

Anderson, P. W. (1972). More is different. *Science, 177*(4047), 393–396. http://doi.org/10.1126/science.177.4047.393.

Arcaro, M. J., & Livingstone, M. S. (2017). Retinotopic organization of scene areas in macaque inferior temporal cortex. *Journal of Neuroscience, 37*(31), 7373–7389. http://doi.org/10.1523/JNEUROSCI.0569-17.2017.

Bates, E., Benigni, L., Bretherton, I., Camaioni, L., & Volterra, V. (1979). *The emergence of Symbols: Cognition and communication in infancy*. New York: Academic Press.

Blank, I. A., Kanwisher, N., & Fedorenko, E. (2014). A functional dissociation between language and multiple-demand systems revealed in patterns of BOLD signal fluctuations. *Journal of Neurophysiology, (Poldrack 2006),* 1105–1118. http://doi.org/10.1152/jn.00884.2013.

Bybee, J. (2010). *Language, usage and cognition.* Cambridge: Cambridge University Press.

Chomsky, N. (1965). *Aspects of theory of language.* Cambridge. MA: MIT Press.

Christiansen, M. H., & Chater, N. (2008). Language as shaped by the brain. *Behavioral and Brain Sciences, 31*(05), 489–558. http://doi.org/10.1017/S0140525X08004998.

Donnai, D., & Karmiloff-Smith, A. (2000). Williams syndrome: From gentotype through to the cognitive phenotype. *American Journal of Medical Genetics, 97*(2), 164–171. http://doi.org/10.1002/1096-8628(200022)97.

Everett, D. L. (2009). Pirahã culture and grammar: A response to some criticisms. *Language, 85*(2), 405–442.

Fedorenko, E., Behr, M. K., & Kanwisher, N. (2011). Functional specificity for high-level linguistic processing in the human brain. *Proceedings of the National Academy of Sciences, 108*(39), 16428–16433. http://doi.org/10.1073/pnas.1112937108.

Futrell, R., Mahowald, K., & Gibson, E. (2015). Large-scale evidence of dependency length minimization in 37 languages. *Proceedings of the National Academy of Sciences, 112*(33), 201502134. http://doi.org/10.1073/pnas.1502134112.

Givón, T. (2001). *Syntax: An introduction, Vol. I.* Amsterdam; Philadelphia: John Benjamins.

Goldberg, A. E. (2006). *Constructions at work: The nature of generalization in language.* Oxford University Press.

Goldberg, A. E. (2016). Subtle implicit language facts emerge from the functions of constructions. *Frontiers in Psychology, 6*(JAN), 1–11. http://doi.org/10.3389/fpsyg.2015.02019.

Gómez, R., & Gerken, L. (2000). Infant artificial language learning and language acquisition. *Trends in Cognitive Sciences, 4*(5), 178–186. http://doi.org/10.1016/S1364-6613(00)01467-4.

Hall, M. L., Ferreira, V. S., & Mayberry, R. I. (2014). Investigating constituent order change with elicited pantomime: A functional account of SVO emergence. *Cognitive Science, 38*(5), 943–972. http://doi.org/10.1111/cogs.12105.

Haspelmath, M. (2008). Parametric versus functional explanations of syntactic universals. *Limits of Syntactic Variation, 132*, 75–107.

Hernandez, A. E., Claussenius-Kalman, H. L. Ronderos, J. Castilla-Earls, A. P., Sun, L., Weiss, S. D., and Young, D.R. (in press). Neuroemergentism: A framework for studying cognition and the brain, Journal of Neurolinguistics.

Herrmann, E., Call, J., Hernàndez-Lloreda, M. V., Hare, B., & Tomasello, M. (2007). Humans have evolved specialized skills of social cognition: The cultural intelligence hypothesis. *Science, 317*(5843), 1360–1366. http://doi.org/10.1126/science.1146282.

Hoffman, E. A., & Haxby, J. V. (2000). Distinct representations of eye gaze and identity in the distributed human neural system for face perception. *Nature Neuroscience, 3*(1), 80–84. http://doi.org/10.1038/71152.

Hopper, P. (1987). Emergent grammar. *Proceedings of the thirteenth annual meeting of the berkeley linguistics society* (pp. 139–157). .

Hudson Kam, C. L., & Newport, E. L. (2009). Getting it right by getting it wrong: When learners change languages. *Cognitive Psychology, 59*(1), 30–66. http://doi.org/10.1016/j.cogpsych.2009.01.001.

Karmiloff-Smith, A. (2006). The tortuous route from genes to behavior: A neuroconstructivist approach. *Cognitive, Affective, & Behavioral Neuroscience, 6*(1), 9–17. http://doi.org/10.3758/CABN.6.1.9.

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Ge, L., & Pascalis, O. (2007). The other-race effect develops during infancy: Evidence of perceptual narrowing. *Psychological Science, 18*(12), 1084–1089. http://doi.org/10.1111/j.1467-9280.2007.02029.x.

Kirby, S. (2000). Syntax without natural selection: How compositionality emerges from vocabulary in a population of learners. In C. Knight, & M. Studdert-Kennedy (Eds.). *The evolutionary emergence of Language: Social function and the origins of linguistic form* (pp. 303–323). Cambridge: Cambridge University Press. http://doi.org/10.1.1.52.8080.

Kirby, S., Tamariz, M., Cornish, H., & Smith, K. (2015). Compression and communication in the cultural evolution of linguistic structure. *Cognition, 141*, 87–102. http://doi.org/10.1016/j.cognition.2015.03.016.
Lander, E. S., & Schork, N. J. (1994). Genetic dissection of complex traits. *Science, 265*(5181), 2037–2048. http://doi.org/10.1126/science.8091226.
Leonard, L. (2014). *Children with specific language impairment.* MIT Press.
Levy, R. (2008). Expectation-based syntactic comprehension. *Cognition, 106*(3), 1126–1177. http://doi.org/10.1016/j.cognition.2007.05.006.
Livingstone, M. S., Vincent, J. L., Arcaro, M. J., Srihasam, K., Schade, P. F., & Savage, T. (2017). Development of the macaque face-patch system. *Nature Communications, 8*.
MacDonald, M. C. (2013). How language production shapes language form and comprehension. *Frontiers in Psychology, 4*.
Mayr, E. (1975). *Evolution and the diversity of life.* Harvard University Press.
Saffran, J. R. (2003). Statistical language learning. *Current Directions in Psychological Science, 12*(4), 110–114. http://doi.org/10.1111/1467-8721.01243.
Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science, 274*(5294), 1926–1928. http://doi.org/10.1126/science.274.5294.1926.
Tomasello, M. (2003). *Constructing a Language: Theory of language acquisition.* Harvard Univ. Press.
Tomasello, M. (2008). *Origins of human communication.* MIT Press.
Traugott, E. C. (2008). Grammaticalization, constructions and the incremental development of language. In R. Eckardt, G. Jäger, & T. Veenstra (Eds.). *Variation, selection, development. Probing the evolutionary model of language change* (pp. 219–250). De Gruyter Mouton.
Traugott, E., & Trousdale, G. (2013). *Constructionalization and constructional changes.* Oxford: Oxford University Press.
Wonnacott, E., Newport, E. L., & Tanenhaus, M. K. (2008). Acquiring and processing verb argument structure: Distributional learning in a miniature language. *Cognitive Psychology, 56*(3), 165–209. http://doi.org/10.1016/j.cogpsych.2007.04.002.