Jaques, N., Lazaridou, A., Hughes, E., Gülçehre, Ç., Ortega, P.A., Strouse, D., … Freitas, N.D. (2019). Social influence as intrinsic motivation for multi-agent deep reinforcement learning. *Proceedings of the 36th International Conference on Machine Learning, PMLR* (Vol. 97, pp. 3040–3049).
Kang, Y., Wang, T., & de Melo, G. (2020). Incorporating pragmatic reasoning communication into emergent language. *Advances in Neural Information Processing Systems*, *33*, 10348–10359.
Kirby, S., Cornish, H., & Smith, K. (2018). Cumulative cultural evolution in the laboratory: An experimental approach to the origins of structure in human language. *Proceedings of the National Academy of Sciences*, *105*, 31.
Kottur, S., Moura, J., Lee, S., & Batra, D. (2017). Natural Language Does Not Emerge 'Naturally' in Multi-Agent Dialog. In *Proceedings of the 2017 Conference on Empirical Methods in Natural Language Processing* (pp. 2962–2967). Association for Computational Linguistics.
Lazaridou, A., & Baroni, M. (2020). Emergent multi-agent communication in the deep learning era. *ArXiv*, abs/2006.02419.
Lazaridou, A., Peysakhovich, A., & Baroni, M. (2017). Multi-agent cooperation and the emergence of (natural) language. *International Conference on Learning Representations*.
Legg, S., & Hutter, M. (2007). Universal Intelligence: A Definition of Machine Intelligence. *Minds & Machines 17*, 391–444.
Lowe, R., Gupta, A., Foerster, J. N., Kiela, D., & Pineau, J. (2020). On the interaction between supervision and self-play in emergent communication. *International Conference on Learning Representations*.
Macpherson, T., Churchland, A., Sejnowski, T., DiCarlo, J., Kamitani, Y., Takahashi, H., & Hikida, T. (2021). Natural and artificial intelligence: A brief introduction to the interplay between AI and neuroscience research. *Neural Networks*, *144*, 603–613.
Mandhane, A., Zhernov, A., Rauh, M., Gu, C., Wang, M., Xue, F., … Mann, T. A. (2022). MuZero with Self-competition for Rate Control in VP9 Video Compression. *ArXiv*, abs/2202.06626.
Mitchell, T., Cohen, W., Hruschka, E., Talukdar, P., Yang, B., Betteridge, J., … Welling, J. (2018). Never-ending learning. *Communications of the ACM*, *61*(5), 103–115.
Moravčík, M., Schmid, M., Burch, N., Lisý, V., Morrill, D., Bard, N., & Bowling, M. (2017). DeepStack: Expert-level artificial intelligence in heads-up no-limit poker. *Science*, *356*(6337), 508–513.
Moreno, P., Hughes, E., McKee, K. R., Pires, B. Á., & Weber, T. (2021). Neural recursive belief states in multi-agent reinforcement learning. *ArXiv*, abs/2102.02274.
Pandia, L., Cong, Y., & Ettinger, A. (2021). Pragmatic competence of pre-trained language models through the lens of discourse connectives. In *Proceedings of the 25th Conference on Computational Natural Language Learning* (pp. 367–379). Association for Computational Linguistics.
Rabinowitz, N., Perbet, F., Song, F., Zhang, C., Eslami, S. M. A. & Botvinick, M. (2018). Machine Theory of Mind. *Proceedings of the 35th International Conference on Machine Learning*, in *Proceedings of Machine Learning Research*, *80*, 4218–4227.
Resnick, C., Gupta, A., Foerster, J., Dai, A. M., & Cho, K. (2020). Capacity, bandwidth, and compositionality in emergent language learning. *International Conference on Autonomous Agents and Multiagent Systems*. https://doi.org/10.48550/arXiv.1910.11424
Sadigh, D., Sastry, S., Seshia, A. S., & Dragan, A. D. (2016). Planning for autonomous cars that leverage effects on human actions. *Robotics: Science and Systems XII*.
Savage N. (2019). How AI and neuroscience drive each other forwards. *Nature*, *571* (7766), S15–S17.
Scott-Phillips, T. C. (2014). *Speaking our minds: Why human communication is different, and how language evolved to make it special*. Macmillan International Higher Education.
Scott-Phillips, T. C., Kirby, S., & Ritchie, G. R. (2009). Signalling signalhood and the emergence of communication. *Cognition*, *113*(2), 226–233.
Silver, D., Hubert, T., Schrittwieser, J., Antonoglou, I., Lai, M., Guez, A., … Hassabis, D. (2018). A general reinforcement learning algorithm that masters chess, shogi, and Go through self-play. *Science*, *362*(6419), 1140–1144.
Strouse, D. J., McKee, K. R., Botvinick, M., Hughes, E., & Everett, R. (2021). Collaborating with humans without human data. *Advances in Neural Information Processing Systems*, *34*, 14502–14515.
Sutton, R. S., & Barto, A. G. (2018). *Reinforcement learning: An introduction*. MIT Press.
Team, Open Ended Learning, et al. (2021). Open-ended learning leads to generally capable agents. *arXiv preprint*, arXiv:2107.12808.
Waymo (2021). Common Waymo One Questions. https://blog.waymo.com/2021/09/common-waymo-one-questions.html
Tolstaya, E., Mahjourian, R., Downey, C., Vadarajan, B., Sapp, B., & Anguelov, D. (2021). Identifying driver interactions via conditional behavior prediction. In *2021 IEEE International Conference on Robotics and Automation (ICRA)* (pp. 3473–3479). IEEE Press.
Turing, A. M. (1950). Computing machinery and intelligence. *Mind*, *LIX*(236), 433–460.
Yang, J., Li, A., Farajtabar, M., Sunehag, P., Hughes, E., & Zha, H. (2020). Learning to incentivize other learning agents. *Advances in Neural Information Processing Systems*, *33*, 1275.

The scaffolded evolution of human communication

Walter Veit[a,b] and Heather Browning[c]

[a]School of History and Philosophy of Science, The University of Sydney, Sydney, NSW 2006, Australia; [b]Department of Psychology, University of Cambridge, Cambridge CB2 3EB, UK and [c]London School of Economics and Political Science, Centre for Philosophy of Natural and Social Science, London WC2A 2AE, UK.
wrwveit@gmail.com; DrHeatherBrowning@gmail.com
https://walterveit.com/; https://www.heatherbrowning.net

doi:10.1017/S0140525X2200070X, e17

Abstract

Heintz & Scott-Phillips provide a useful synthesis for constructing a bridge between work by both cognitive scientists and evolutionary biologists studying the diversity of human communication. Here, we aim to strengthen their bridge from the side of evolutionary biology, to argue that we can best understand ostensive communication as a scaffold for more complex forms of intentional expressions.

While the Darwinian revolution has taken much of the force from the idea that humans are separate from the rest of nature, there is no doubt that one of our unique traits is the diversity and open-endedness of our means of expression; constituting something of a major transition in the evolution of our hominid ancestors. Yet, in order to begin an evolutionary investigation into how and why this happened, we require an integration of many sources of data from different fields that have hitherto largely operated independently. It is just such an empirical synthesis that has been offered in the present target article by Heintz and Scott-Phillips (H&S-P). They provide what is effectively a breakdown of the components of human communication to enable an evolutionary reverse-engineering approach for understanding the evolution of this rich, diverse, and open-ended capacity of humans and allowing us to begin the construction of a bridge between the work of evolutionary biologists and cognitive scientists interested in human communication.

Yet we maintain that this bridge could be strengthened on the evolutionary side. The authors maintain, similarly to Heyes (2019), that evolutionary biologists have remained "cognition blind" – failing to adequately take into consideration the progress computational cognitive science has made in understanding the mind, and instead relying upon needlessly simplistic and mechanistic "hardware" (as opposed to "software') models. While this is certainly true to some extent (Morin, 2016), the criticism can cut both ways and we should likewise not underestimate the blindness of many cognitive scientists towards the resources of modern evolutionary biology. As an example for "cognition blindness," H&S-P argue that the common division of expressive behaviours such as language, instruction, and the like, which they maintain could be seen as part of a single cognitive capacity for ostensive communication. However, by using the analogy of running and walking as subfunctions of a more general capacity for bipedal locomotion it should be clear that the division of capacities into subfunctions is not because of a blindness to cognitive

https://doi.org/10.1017/S0140525X22000012 Published online by Cambridge University Press

mechanisms. It is the tried-and-proven evolutionary method of reverse engineering to make sense of the phylogeny of different functional capacities of organisms. But it remains still too rare an occurrence that the teleonomic question is asked regarding what cognition is – or particular cognitive capacities such as communicative ability are – *for*, especially in the case of humans. There is thus a need for further attention on both sides.

In particular, we think that the bridge between evolutionary biologists and cognitive scientists could be strengthened by considering recent work on "scaffolding" in evolution (Caporael, Griesemer, & Wimsatt, 2014; Sterelny, 2006; Veit, 2022). Scaffolding refers to traits that facilitate the evolution or for that matter the development of other traits, and may then themselves eventually be lost or repurposed, which could have happened in the evolution of the distinct modes of human expression. If the diversity of human forms of expression has a common evolutionary origin, we would then expect to trace back the evolutionary history to find something like a common scaffold, one that was eventually discarded or at least transformed. While this terminology is not used by H&S-P, their proposal that ostensive communication is the common functional core of human communication can be better understood as the claim that direct ostensive communication (i.e., action grounded in communicative intentions) served as an evolutionary scaffold for the evolution of more complex intentional capacities, such as those they describe.

Ostensive communication can additionally be seen as a developmental scaffold as much as an evolutionary scaffold. While development should not be taken to track phylogeny, it can still provide evidence regarding the evolutionary functions and origins of traits; in this case human communication. In the early stages of human development, communication very much proceeds by overtly intentional actions such as pointing (Camaioni, Perucchini, Bellagamba, & Colonnesi, 2004; Grassmann & Tomasello, 2010), a behaviour that decreases as an individual learns more complex forms of intentional expression. The evolution of humans has not yet led to discarding the older mechanism, suggesting that it is of central importance. This indicates that the simpler intentional actions serve to scaffold the development of more complex communication within the learning history of an individual, as well as the evolutionary history of a lineage. These dual lines of support lend further credence to the proposed importance H&S-P place on the cognitive mechanisms they describe.

Finally, in investigating this proposal, we urge for more research into the distribution and development of more complex forms of intentional expression in other species. Particularly in our close relatives, the great apes, their capacities may provide useful clues regarding human evolution and why the structures of great ape societies give rise only to prototypical forms of these capacities. As the authors discuss, it seems that apes are able to develop some traits when raised in more altruistic or cooperative human environments, but their natural social contexts seemingly prevent it. A nice example of this type of ability comes from the observations by Russon and Andrews (2011) on orangutans at Camp Leakey. Here, they catalogued repeated instances of orangutans spontaneously "pantomiming" (i.e., gesturing in which the meaning is "acted out" by the orangutan). Where communication initially failed, some individuals would attempt to rectify the failure through seeking the attention of their audience, and subsequent repetitions or elaborations. These are arguably examples of an individual working to make their communicative intention clear; of ostensive communication. While this context differs of course from orangutan natural social ecology, it provides a nice example of the potential ways in which more complex forms of communication can be scaffolded and thus provides some insights into how they could have gradually emerged in our lineage.

We think that understanding the evolution of human communicative abilities through the framework of evolutionary scaffolding will help us to strengthen the bridge between work on the evolution of animal communication and the cognitive science of human communication, as well as suggest ways for the integration and cross-collaboration of future work.

Financial support. WV's research was supported under Australian Research Council's Discovery Projects funding scheme (project number FL170100160).

Conflict of interest. None.

References

Camaioni, L., Perucchini, P., Bellagamba, F., & Colonnesi, C. (2004). The role of declarative pointing in developing a theory of mind. *Infancy*, *5*(3), 291–308.

Caporael, L. R., Griesemer, J. R., & Wimsatt, W. C. (2014). *Developing scaffolds in evolution, culture, and cognition* (Vol. *17*). MIT Press.

Grassmann, S., & Tomasello, M. (2010). Young children follow pointing over words in interpreting acts of reference. *Developmental Science*, *13*(1), 252–263.

Heyes, C. (2019). Cognition blindness and cognitive gadgets. *Behavioral and Brain Sciences*, *42*, e187.

Morin, O. (2016). *How traditions live & die*. Oxford University Press.

Russon, A., & Andrews, K. (2011). Orangutan pantomime: Elaborating the message. *Biology Letters*, *7*(4), 627–630.

Sterelny, K. (2006). The evolution and evolvability of culture. *Mind & Language*, *21*(2), 137–165.

Veit, W. (2022). Scaffolding natural selection. *Biological Theory*, *17*, 163–180. https://doi.org/10.1007/s13752-021-00387-6

The central problem is still evolutionary stability

Sławomir Wacewicz and Przemysław Żywiczyński

Center for Language Evolution Studies, Nicolaus Copernicus University in Toruń, 87-100 Toruń, Poland.
wacewicz@umk.pl; Przemyslaw.Zywiczynski@umk.pl
https://cles.umk.pl/

doi:10.1017/S0140525X22000723, e18

Abstract

We applaud Heintz & Scott-Phillips's guiding metaphor of "unleashing leashed expression," and we value the unified explanation for the emergence of not only language, but also other forms of unleashed expression, such as multimodal communication. We are more critical of the authors' discussion of the selection pressures acting towards unleashed expression, which are proposed to hinge on partner choice ecology.

In their target article, Heintz & Scott-Phillips (H&S-P) effectively confirm that the central problem for the emergence of domain-general, open-ended communication (including language) is its evolutionary stability. Their account is one of the rare few that takes this challenge seriously and does not presuppose human communication to be special. H&S-P rightly observe that "all

https://doi.org/10.1017/S0140525X22000012 Published online by Cambridge University Press