Processing negation demonstrates compositionality in rhesus macaques

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Animals exhibit a vast array of complex communication systems, including referential vocalizations (Townsend & Manser, 2013), and elaborate combinations of calls (Suzuki et al., 2018). However, amongst all of animal communication, human language stands out as unique in its complexity and vast expressive power (Berwick & Chomsky, 2016; Hauser et al., 2002). Language allows a finite vocabulary of words to express theoretically infinite ideas via the process of 'compositionality', the ability to combine words and phrases into higher level representations (Chomsky, 1965; Hauser et al., 2002). While there is evidence of call combinations in non-human primates (e.g. Arnold & Zuberbühler, 2006), these combinations are minimal, resulting in limited expressivity compared to language (Zuberbühler, 2018). Despite this lack of compositionality in primate communication, here we ask whether they might be capable of compositional processes in a non-communicative, experimental setting. We developed a series of novel, non-linguistic 'negation' experiments, making use of the fact that negative clauses (e.g., 'not red') are necessarily compositional; the meaning of the phrase cannot be derived from either word in isolation (Dautriche et al., 2022). We specifically asked whether macaques could learn that a label represented the concept of negation (i.e., meant 'not'), and whether they could use that label compositionally to correctly interpret and respond to novel negative clauses (e.g., 'not triangle'). In Experiment 1, we presented six rhesus macaques with two choice stimuli, alongside a cue denoting which choice stimulus to select. The cue was either an iconic image matching the choice they should select, or the same image paired with the negation signal, in which case the non-matching choice stimulus should be selected. Critically, on all trials the choice stimuli were novel, to avoid learning about individual stimuli and to require generalization. All monkeys solved this task, combining the cue and label on a trial-by-trial basis to select the appropriate choice stimulus. However, in Experiment 1, it was possible that the monkeys had not actually learned the meaning of the negation label, and instead were simply using its presence as a context cue, denoting whether they should select the matching or mismatching stimulus. Therefore, in Experiment 2, we added a 'positive' label to positive trials, to require the monkeys to attend to the identity of these labels. Monkeys initially treated all trials as 'negation' trials and performed below chance on positive conditions. Over time, performance devolved to simply guessing. These results show that in Experiment 1 the macaques did not actually learn the meaning of the negation label, but were rather using the presence of any label at all as a context cue. However, in Experiment 3, we used novel training methods across three phases to simultaneously teach both positive and negation labels. With substantial training, the monkeys successfully learned this task, demonstrating that they can identify both the positive and negation labels, and combine them compositionally with novel cues on a trial-by-trial basis. Our results provide strong experimental evidence for compositionality in non-human primates, suggesting the core of this ability may not be unique to humans.

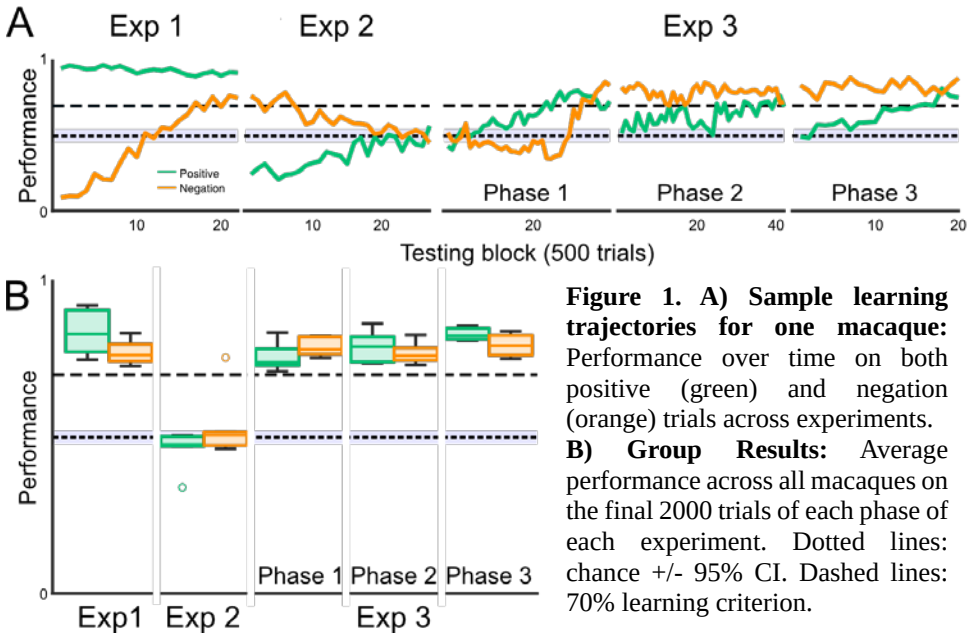

Figure 1. A) Sample learning trajectories for one macaque: Performance over time on both positive (green) and negation (orange) trials across experiments. **B) Group Results:** Average performance across all macaques on the final 2000 trials of each phase of each experiment. Dotted lines: chance +/- 95% CI. Dashed lines: 70% learning criterion.

References

Arnold, K., & Zuberbühler, K. (2006). Semantic combinations in primate calls. *Nature*, *441*(7091), Article 7091. https://doi.org/10.1038/441303a

Berwick, R. C., & Chomsky, N. (2016). *Why Only Us: Language and Evolution*. MIT Press.

Chomsky, N. (1965). *Aspects of the Theory of Syntax*. MIT Press. https://apps.dtic.mil/sti/pdfs/AD0616323.pdf

Dautriche, I., Buccola, B., Berthet, M., Fagot, J., & Chemla, E. (2022). Evidence for compositionality in baboons (Papio papio) through the test case of negation. *Scientific Reports*, *12*(1), Article 1. https://doi.org/10.1038/s41598-022-21143-1

Hauser, M. D., Chomsky, N., & Fitch, W. T. (2002). The faculty of language: What is it, who has it, and how did it evolve? *Science*, *298*, 1569–1579. https://doi.org/10.1126/science.298.5598.1569

Suzuki, T. N., Wheatcroft, D., & Griesser, M. (2018). Call combinations in birds and the evolution of compositional syntax. *PLOS Biology*, *16*(8), e2006532. https://doi.org/10.1371/journal.pbio.2006532

Townsend, S. W., & Manser, M. B. (2013). Functionally Referential Communication in Mammals: The Past, Present and the Future. *Ethology*, *119*(1), 1–11. https://doi.org/10.1111/eth.12015

Zuberbühler, K. (2018). Combinatorial capacities in primates. *Current Opinion in Behavioral Sciences*, *21*, 161–169. https://doi.org/10.1016/j.cobeha.2018.03.015

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