RATIONAL AFTER ALL: CHANGES IN PROBABILITY MATCHING BEHAVIOUR ACROSS TIME IN HUMANS AND MONKEYS

CARMEN SALDANA[*1,2,3], NICOLAS CLAIDIÈRE[4,5], JÖEL FAGOT[4,5], and KENNY SMITH[1]

[*]Corresponding Author: carmen.saldanagascon@uzh.ch
[1]Centre for Language Evolution, University of Edinburgh, Edinburgh, UK
[2]Center for the Interdisciplinary Study of Language Evolution, University of Zurich, Zurich, CH
[3]Department of Comparative Linguistics, University of Zurich, Zurich, CH
[4]Aix-Marseille University, CNRS, LPC, Marseille, FR
[5]Brain and Language Research Institute, Aix-Marseille University, Aix-en-Provence, FR

Probability matching strategies have long been thought to be characteristic of human performance in probability learning tasks in a variety of contexts, from decision making to language learning. Probability matching occurs when subjects given probabilistic input respond in a way that is proportional to the input probabilities. However, such behaviour is not optimal in a decision theoretic sense; the optimal decision strategy is to always select the variant with higher positive-outcome probability, known as maximising (or regularising, for linguistic tasks).

Propensity to probability match may differ across ages and species. While adults probability match in probability learning tasks, children tend to use maximising strategies instead: this difference across ages has been shown in linguistic as well as non-linguistic tasks (e.g., Derks & Paclisanu, 1967; Hudson Kam & Newport, 2005). However, more recent work comparing probability matching behaviour across linguistic and non-linguistic domains further suggests that adults are less likely to probability match in linguistic tasks (Ferdinand, Kirby, & Smith, 2019). Linguists have taken these differences across age groups and domains to suggest that regularisation of unconditioned linguistic variation over time might be driven by domain-specific biases as well as by domain-general biases not specific to humans. While very few studies have directly compared behavioural differences between primate species, existing studies suggest that monkeys ($N = 2$ to 8), unlike humans, adopt maximisation strategies (Parrish, Brosnan, Wilson, & Beran, 2014). These results suggest that probability matching behaviour might be restricted to adult humans, and perhaps most evident in non-linguistic domains. However, we lack direct robust evidence from the differences between human and non-human primate behaviour in simple decision making tasks, and a thorough exploration of how probability matching behaviour develops across time.

Here we present a series of experiments designed to directly compare probability matching behaviour across time in adult humans and Guinea baboons

(*Papio papio*) with a hitherto unmatched sample size (up to $N = 20$ baboons). The preregistered design and analysis plan for these experiments is accessible at `osf.io/qnm57`. We ran two experiments with different reward regimes. In Experiment 1 subjects were rewarded probabilistically (baboons, with food; humans, with money); in Experiment 2 subjects were always rewarded regardless of their response, lowering the cost of probability matching. In each experiment, we further manipulated the number of shapes (two or three) and reward probability (skewed or uniform). On each trial, subjects saw a set of coloured shapes (two or three shapes, randomly positioned on a computer screen) and were prompted to select one. Each shape lead to a reward according to the input ratio in the condition—70:30 (skewed, two shapes), 70:15:15 (skewed, three shapes), 50:50 (uniform, two shapes) or 33:33:33 (uniform, three shapes). If the subject selected the target shape for a given trial, they were rewarded. If the target shape was not touched, the subject proceeded to the next trial without reward (in Experiment 1) or to a recovery trial (in Experiment 2); in the recovery trial, the target image would be highlighted, subjects were prompted to select it and were then rewarded. Participants completed at least 240 trials. All factors were manipulated within-subjects for baboons ($N = 20$) and between-subjects for humans ($N = 160$).

In Experiment 1, where reward was probabilistic and the distribution of reward was skewed (i.e. 70:30 or 70:15:15), both species initially showed probability matching followed by a switch to maximising: in the first block of 60 trials, the selection of the shape with the highest reward probability was not significantly different from its reward probability, but there was a significant increase of maximising behaviour by block and final convergence to maximising behaviour after 240 trials. Crucially, we found probability matching behaviour in both species when the reward distribution was uniform. This difference in behaviour between skewed and uniform conditions suggests that maximising is not the default strategy but that both species are sensitive to the availability of maximising strategies.

In Experiment 2, in which reward was always available, we found that humans behaved as in Experiment 1 (i.e. probability matching then maximising with skewed and not with uniform distributions) but baboons responded randomly in all conditions (i.e. selecting all shapes with equal probability). These results suggest that humans maximised even when probability matching behaviour was not (monetarily) penalised, thus suggesting that maximising strategies in humans, unlike in baboons, are not uniquely driven by reward.

Our study provides evidence against the common assumption that humans probability match in simple decision making tasks and raises questions over the validity of conclusions in standard behavioural experiments, which our results suggest may simply have insufficient trials to show maximising or hide differences across time. It also casts doubt on the suggested domain-specific sources of maximising behaviour in linguistic tasks by providing evidence of shared maximising mechanisms in probability learning across primate species in non-linguistic tasks.

References

Derks, P. L., & Paclisanu, M. I. (1967). Simple strategies in binary prediction by children and adults. *Journal of Experimental Psychology*, *73*(2), 278.

Ferdinand, V., Kirby, S., & Smith, K. (2019). The cognitive roots of regularization in language. *Cognition*, *184*, 53–68.

Hudson Kam, C. L., & Newport, E. (2005). Regularizing Unpredictable Variation: The Roles of Adult and Child Learners in Language Formation and Change. *Lang. Learn. Dev.*, *1*(2), 151–195.

Parrish, A. E., Brosnan, S. F., Wilson, B. J., & Beran, M. J. (2014). Differential Responding by Rhesus Monkeys (Macaca mulatta) and Humans (Homo sapiens) to Variable Outcomes in the Assurance Game. *Anim. Behav. Cogn.*, *1*(3), 215–229.