Supplementary Information for *Ape cultures do not require behavior copying*

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Additional model information

This document provides additional information on the individual-based model desribed in the paper *Ape cultures do not require behavior copying.* The full code to run the model and to reproduce the results can be found in https://github.com/albertoacerbi/oranzees, together with a detailed documentation of the model development.

The oranzees' world

The oranzees model is an individual-based model, fully written in R, that reproduces a world where six populations of "oranzees" (a hypothetical ape species) live. The model is spatially-explicit: the six populations are located at relative positions analogous to the six populations of chimpanzees in Whiten et al. (1999), see Figure 1. For modelling convenience, we put these locations approximately in the centre of a 1000 x 1000 squared environment in order to be able to process their relative distances, that we use to calculate genetic propensity and ecological availability of the behaviors (see below).

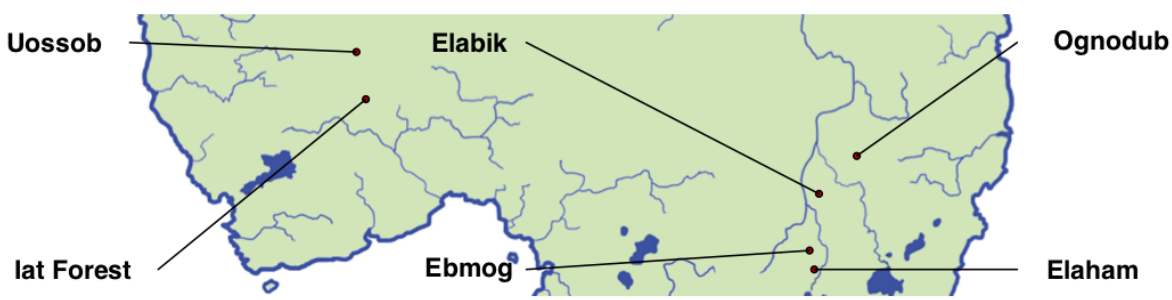

Figure 1: Location of the six populations of oranzees.

The population sizes are also taken from the real chimpanzees populations considered in the study above. Following Lind and Lindenfors (2010), we use data from Wrangham (2000):

Group	Population size
Uossob	20
Elabik	42
Ognodub	49
Iat Forest	76
Ebmog	50
Elaham	95

Geographical gradient for genetic propensity and ecological availability

As described in the main manuscript, two parameters of the models, α_g and α_e, determine the probability that the genetic propensity and ecological availability associated to the behaviors are equal for all the six populations, or if they differ among the populations.

Independently for each behavior, if genetic propensity (or ecological availabilty) is equal, the probability associated (p_g or p_e) is a randomly drawn number between 0 and 1, the same for all six populations. If they are not equal, the values of p_g (or p_e) are assigned using a geographical gradient, by choosing a random point in the oranzees' world, and calculating its distance to each population. Distances are then transformed to p_g (or p_e) by rescaling them between 0 and 1, so that for the farther population $p_g = 0$ i.e. the associated behavior will be impossible to express (or $p_e = 0$ i.e. the associated behavior will be absent with an "ecological explanation").

In the example in Figure 2, a particular behavior will have $p_g = 1$ (or $p_e = 1$) in the Ognodub site, $p_g = 0$ (or $p_e = 0$) in Iat Forest and Uossob, and intermediate values in the other sites.

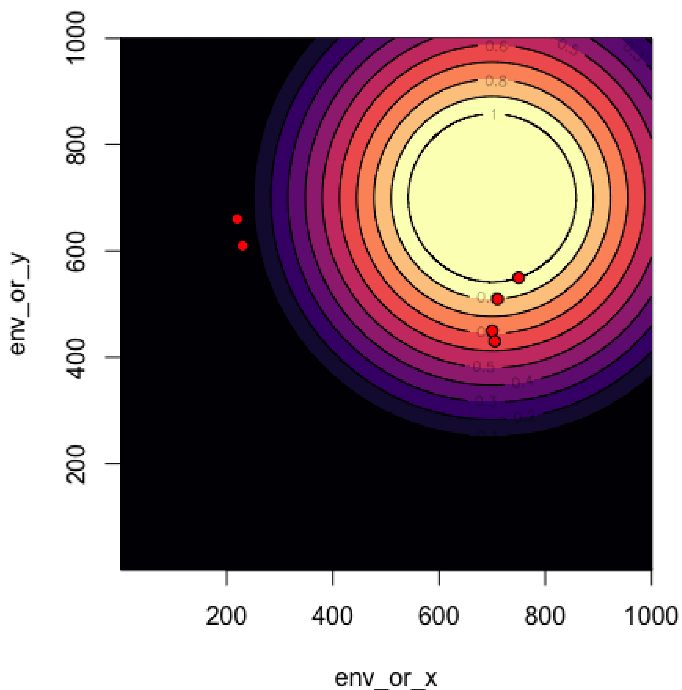

Figure 2: Example of calcualtion of p_g (or p_e). The red points represent the oranzee populations. The color gradient represents the value of p_g (or p_e).

Sub-categories of behaviors

There are 64 behaviors possible in the model (inspired by the 65 coded in Whiten et al. (1999)), divided in two main categories: "social" and "food-related". Each category is further subdivided in sub-categories. Sub-categories, for food-related behavior, are further assigned to specific "nutrients". This information is used to calculate the oranzee's state according to its behavior (see main manuscript). The names of behaviors and of the sub-categories are only evocative. They are used to illustrate our results in Figure 2 (main manuscript).

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Social

Sub-category	Behavior
Play	fruit-missile
Play	slap-fight
Play	air-split
Play	leaf-mask
Play	whistle
Play	pebble-tease
Play	tumbling
Play	brick-fall
Display	stone drop
Display	branch pull-release
Display	arm-cross
Display	two-hand-drum
Display	splash
Display	arm-swing
Display	explode-leaf
Display	contorsionist
Groom	tool back-scratcher
Groom	hand back-scratcher
Groom	tongue-bathe
Groom	tooth-pick
Groom	dirt-shower
Groom	ant-shower
Groom	q-tip
Groom	exfoliate-fruit
Courtship	flower-offer
Courtship	hand-stand
Courtship	rope-swing
Courtship	leaf-fan
Courtship	wreath-clutch
Courtship	ear-pull
Courtship	kissy-hand
Courtship	hop-dance

Food-related

Sub-category	Behavior	Nutrient
Fruit-hammer foraging	wood-wood	Y
Fruit-hammer foraging	wood-stone	Y
Fruit-hammer foraging	stone-wood	Y
Fruit-hammer foraging	stone-stone	Y
Fruit-hammer foraging	bone-wood	Y
Fruit-hammer foraging	bone-stone	Y
Fruit-hammer foraging	wood-ground	Y
Fruit-hammer foraging	stone-ground	Y
Stick-based foraging	stick-throw V	Z
Stick-based foraging	stick-throw A	Z
Stick-based foraging	fish-stab	Z
Stick-based foraging	hedgehog-flick	Z
Stick-based foraging	worm-hook	Z
Stick-based foraging	bird-probe	Z
Stick-based foraging	fish-hammer	Z
Stick-based foraging	spin-seed	Z
Anvil smash	anvil-smash S	Y
Anvil smash	anvil-smash W	Y
Anvil smash	smash-ground	Y
Anvil smash	drop-ground	Y
Rolling pin tecniques	rolling-wood	Z
Rolling pin tecniques	rolling-stone	Z
Rolling pin tecniques	rolling-bone	Z
Rolling pin tecniques	rolling-other	Z
Insect swatting	bug-clap	Y
Insect swatting	stick-insect	Y
Fish stunning	fish-stun-stone	Z
Fish stunning	fish-stun-wood	Z
Tortoise-flip	tortoise-drop-on-stone	Y
Potato-mash	tuber-mash	Z
Clubbing	mammal-clubbing	Y
Egg cracking	egg-crack	Z

Example of single run

Figure 3 shows an example of the entire history of all behaviors in a single run, for a single population (geographical location and population size are based on "Uossob"), with $\alpha_g = 0.2$, $\alpha_e = 0.8$, and $S = 1$, i.e. one of the combination of parameters that produces a number of cultural behavior similar to Whiten et al. (1999).

S (plural)

Figure 3: Example of a single run with $\alpha_g = 0.2$, $\alpha_e = 0.8$, and $S = 1$. The plots show the frequencies of the 64 possivble behaviors, divided in panles by sub-category.

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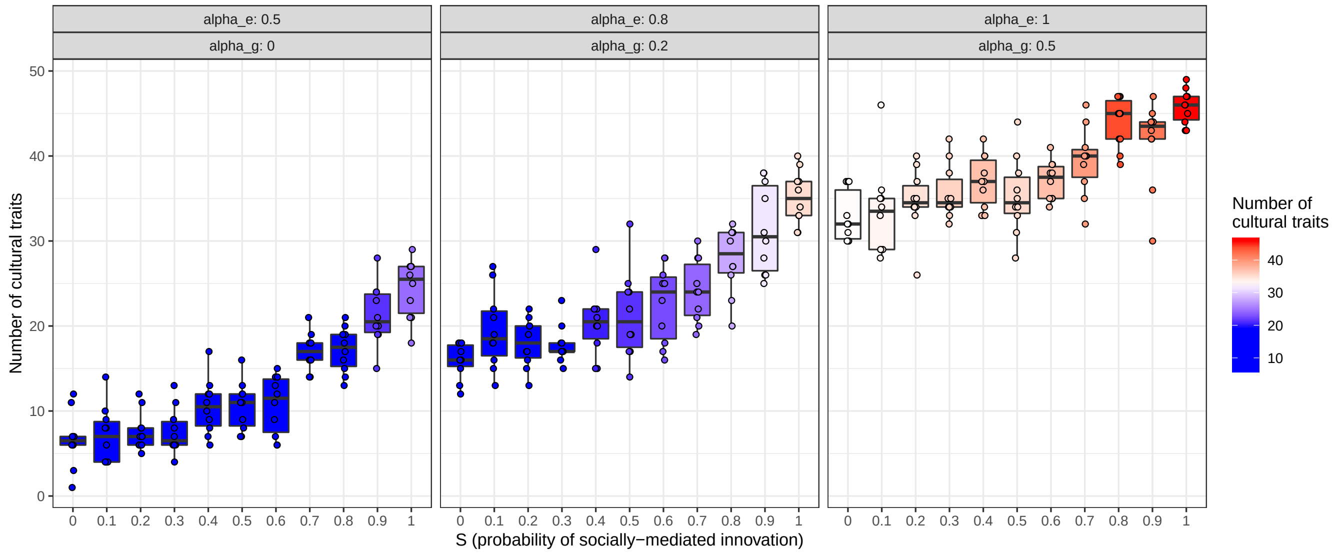
Age classes to calcualte customary behaviors

To determine *customary* behaviors, we need to define age classes for individuals (the definition of customary behaviors, from Whiten et al. (1999) is a behavior observed in over 50% of individuals in at least one age class). We define three age classes as follows:

- *adults*: individuals that are more than 16 years old.
- *subadults*: individuals between 8 and 16 years old.
- *juveniles*: individuals that are less than 8 years old.

Supplementary figures

Figure S4



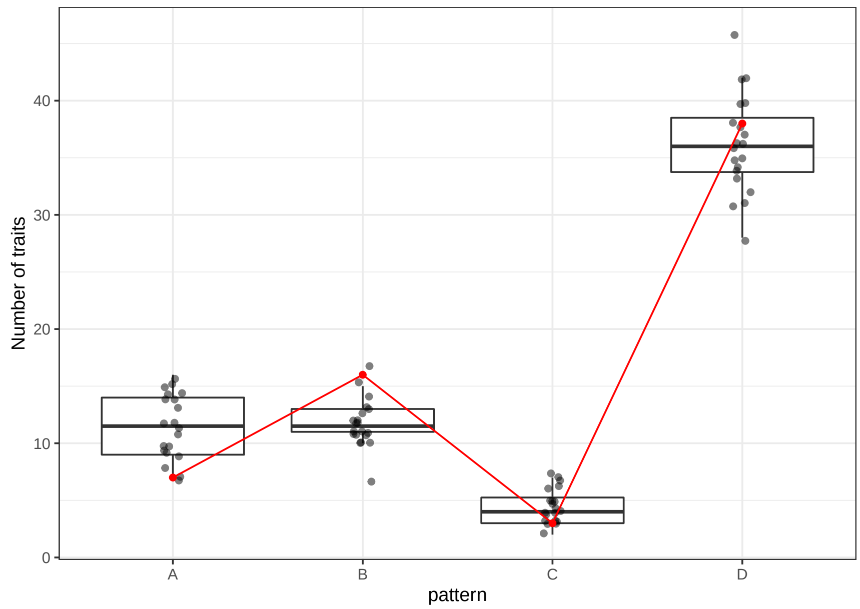
after

Figure 4: Cultural traits in oranzees, varying the probability of socially-mediated innovations. Red color indicates simulation runs that produced more than 38 cultural behaviors;* blue color indicates simulation runs that produces less than 38 cultural behaviors. S, α_e and α_g as indicated in the plot. $N = 10$ runs for each parameters combination.

combination
of parameters

*(the number of cultural traits
identified by W et al)

Figure S5



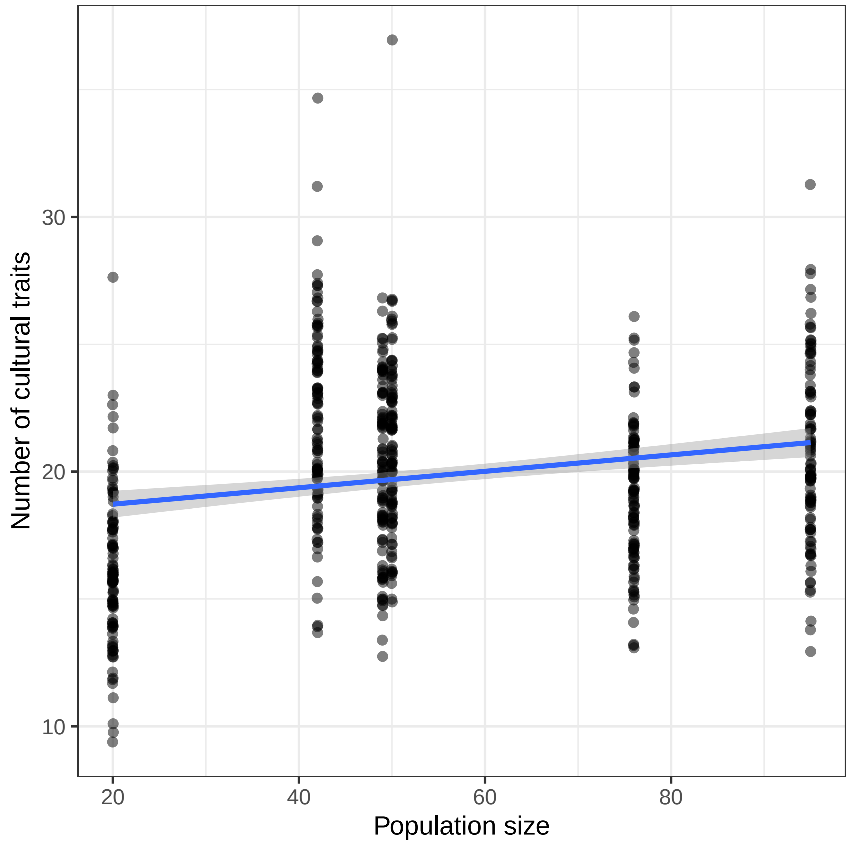
traits

link to descript.

Figure 5: Number of behaviors for each of the four patterns (*A*, *B*, *C*, *D*) for the parameters $\alpha_e = 0.8; \alpha_g = 0.2, S = 1$. The red values are the values described for real chimpanzees populations. $N = 20$ runs.

of patterns

Figure S6



traits

Figure 6: Number of cultural behaviors for each population for the parameters $\alpha_e = 0.8; \alpha_g = 0.2, S = 1$. The blue line is a linear fit of the data. $N = 100$ runs.

References

Lind, Johan, and Patrik Lindenfors. 2010. “The Number of Cultural Traits Is Correlated with Female Group Size but Not with Male Group Size in Chimpanzee Communities.” *PLoS ONE* 5 (3). https://doi.org/10.1371/journal.pone.0009241.

Whiten, A., J. Goodall, W. C. McGrew, T. Nishida, V. Reynolds, Y. Sugiyama, C. E. G. Tutin, R. W. Wrangham, and C. Boesch. 1999. “Cultures in Chimpanzees.” *Nature* 399 (6737): 682–85. https://doi.org/10.1038/21415.

Wrangham, Richard W. 2000. “Why Are Male Chimpanzees More Gregarious Than Mothers? A Scramble Competition Hypothesis.” In *Primate Males: Causes and Consequences of Variation in Group Composition*, 248–58. Cambridge: Cambridge University Press.