Social learning of pottery-making techniques
An Agent Based Model to understand the amphorae production patterns in the Roman Empire

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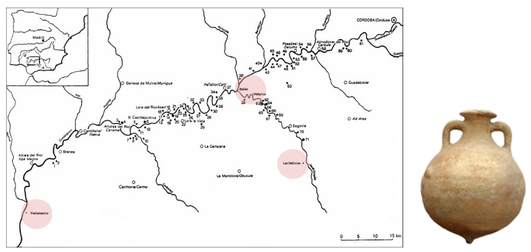
Introduction

Material culture variability allows us to interpret the change in the production processes [1]. In particular, this study is exploring this question by analyzing large-scale amphorae production during the Roman Empire. Specifically, we are interested on understanding if pottery-making techniques were transmitted through vertical or horizontal social learning. If vertical is the one in use, amphorae made in nearby workshops might share more similar traits than amphorae made from farthest workshops, following isolation-by distance [2]. We test it by observing the existence of a correlation between spatial distance and morphometric variation. In this work we have explored the social learning processes associated with amphorae production through a combination of empirical analysis and theoretical exploration.

Materials

We analyzed 413 amphorae (fig.1 (b)) from 4 different workshops located in *Baetica* (fig.1 (a)). This province supplied a massive quantity of olive oil to the rest of the Empire from the Ist to the IIIrd centuries, and for this reason a large-scale infrastructure of amphorae production was developed here. The same amphoric type (Dressel 20) was produced in several workshops located along the course of the Guadalquivir river. A sample of 90 amphorae was chosen for each of the four analysed workshops. Eight different measures were taken for each amphorae, most of them focused on the rim as this was the best preserved component of the artifacts.



(a) (b)

Figure 1: a) More than 80 pottery workshops were distributed along the Guadalquivir river and its tributary the Genil. Red circles belong to the workshops analyzed. b) The entire sample is composed of Dressel 20 amphorae

Empirical Analysis

Methods

Principal Component Analysis (PCA) allowed us to capture most of the variance of the 8 measurements into 2 variables.

Results

The patterns observed in the first 2 Principal Components suggests that amphorae from closer workshops tend to be more similar (see Figure 2). In particular, the three closest workshops show variation on PC1 (i.e. Belén, Delicias and Malpica) while Parlamento displays a distinctive pattern than the rest of workshops on PC2 values.

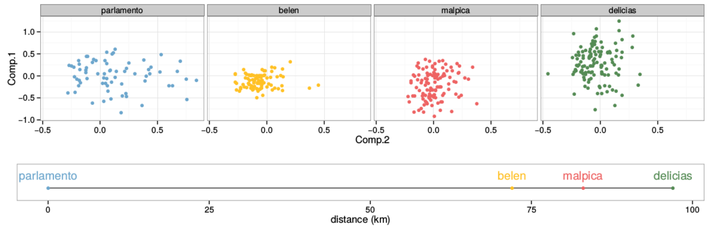


Figure 2: First and Second Principal Components for amphorae measured from the 4 analysed workshops

Theoretical Exploration

Model

The observed pattern was further explored with a model based on classical random drift [3]. This approach allow us to test the impact of horizontal vs vertical transmission (HT vs VT) on the variation in production between workshops. We define a set Pop of N workshops sharing the same initial production techniques P^0 and positioned along a line at increasing distances (all workshops are positioned along the same river course). Each workshop produce amphorae and change their production techniques by 1) modifying their own techniques or 2) copying one from another workshop.

The algorithm is defined as following:

INITIALIZATION:
for $i \in Pop$ **do**
  $P^i = P^0$
end for
SIMULATION:
loop $step \in TimeSteps$
  for $i \in Pop$ **do**
    $AmphoraProduction(P^i)$
    if $(step \mod 100) = 0$ **then**
      $P^i = Innovation(P^i)$ ▷ Vertical Transmission
      $P^i = RandomCopy(Pop)$ ▷ Horizontal Transmission
    end if
  end for
end loop

Experiment & Result

To test the impact of the distance we bias the random copy toward the closest neighbour. We define $P(T_{AB})$ the probability that WS_A copy WS_B as $\frac{1}{f(d)}$, where d is the distance between A and B. Three level of bias are tested. For each level we run 100 simulations with 4 workshops. Amphorae are describe by on trait and we look how this trait varies between each workshop at the end of the simulation.

Figure 3 shows that variation in production is high only if there is no HT or if the transfer is strongly biased toward the closest neighbour.

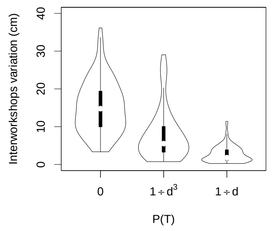


Figure 3: Inter-workshop variation of the mean of the trait after 10 000 timestep in setup where the horizontal transfer probability varies (100 simulations per condition).

Discussion

Empirical studies have identified variation on the making techniques processes among pottery workshops. We observe that this variability is affected by the distance: the analysed morphometric traits show that the similarity between amphorae decrease with the spatial distance between the workshops they were produced.

The combination of this empirical analysis with the theoretical model suggests that horizontal transmission could not be the main cultural process in the workshops. Vertical transmission seems to be the most probable mechanism. This can be interpreted by the fact that pottery techniques were learned from master to disciple and that disciples remained in the workshop where they were trained.

References

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Acknowledgements

The Funding for this work was provided by the ERC Advanced Grant EPNet (340828).

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