

Another glass of failure? ☆

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Abstract

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Keywords: Cultural Evolution, Roman Empire, amphorae production, social learning

1. Introduction

xavi: Comentario general: por que cada frase la has puesto en un paragrafo distinto? Cada paragrafo deberia ser un tema y no una frase. Y deberias usar el concepto de topic sentence (la primera frase del paragrafo resume el paragrafo).

5 maria: si, claro, lo tengo que cambiar en el momento en el que incluya las imagenes. Lo deje asi porque era el primer draft :D

xavi: Esto va al JAS no? La primera frase deberia tener un tono mas arqueologico.

10 maria: he cambiado el prrafo para que parezca mas arqueologico :D

Material culture variability allows to understand a part of the mechanism of the human behaviour (Basalla, 1988; Schillinger et al., 2016a). Dynamic of

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¹Since 1880.

changes on the material culture have been analyzed by the study of cultural
15 pattern which varying over time and space (Eerkens, Jelmer and Lipo, Carl
P., 2007; Lycett, 2015) The detection of those different patterns in artefact
production in the archaeological records could also explain whether these change
are produced by cultural reasons or not based on economical, political and social
changes. maria: CITATION NEEDED

20

As result, different information are shared by social learning generating an
accumulation of knowledges which are transmitted from generation to genera-
tions in different context and content conditions (Eerkens and Lipo, 2005; Neff,
1992; Henrich and McElreath, 2003; Boyd et al., 2011). Likewise, the mode
25 of learning transmission, along with several external conditions might affect
directly or indirectly the pattern of manufacturing of the artefacts.

Within evolutionary perspective, social learning is analyzed to understand
the human behaviour in archaeology. Thought material culture, we can observe
cultural pattern which can explain how the culture evolve (Richerson and Boyd,
30 2005)

However, different debates revolve around how individuals or groups ac-
quired and transmitted techniques skills (Bowser and Patton, 2008; Mesoudi
and O'Brien, 2008). In addition, this challenge is combined with the difficulty
detecting the different modes of transmission in the archaeological record (Roux,
35 2015). In the case of archaeology, several studies have analysed this process fo-
cused on the production of handmade pottery (Steele, James et al., 2010) or
stylistic variations (Neiman, 1995; Shennan and Wilkinson, 2001). Specifically
our work pretend to know if those processes could be similar with a more stan-
dardized and massive production (Gandon et al., 2014), focused on the case of
40 pottery production in the Roman Empire.

maria: terminar cultural evolution

xavi: Esta frase no dice realmente nada no? Debes ser mas concreta y concisa
en lo que quieres transmitir. Dando la vuelta al tema, podrias estructurar el
mismo contenido asi: 1. la cultural material que los arqueologos encuentran esta

45 basada siempre en social learning, 2. la arqueología evolutiva analiza el proceso
para saber que tipo de social learning se esta usando, 3. la mayoría de estudios
se centran en cerámica hecha a mano y variaciones estilísticas 4. creemos que
este framework es aplicable a otros contextos y objetivos, como entender los
procesos masivos de producción de ánforas en el imperio romano

50

This paper explores the changes in the production processes during the Roman Empire. In particular, our study is focused on understanding the pottery-making techniques by analyzing large-scale amphorae production in a specific area. In this case, an evolutionary framework is used for studying the impli-
55 cation and the impact that this production might involve on the evolution of social learning processes.

xavi: Este es el tema principal del paper; debería ser explicitado antes y un poco mas detallado: 1. queremos entender los procesos productivos del imperio romano, 2. en concreto, la producción en masa de ánforas, 3. la aplicación de
60 un framework evolutivo nos permitiría identificar que tipo de social learning está envuelto.

Specifically, the aim of this study is understanding if pottery-making techniques were transmitted through vertical or horizontal social learning. Our
65 main hypothesis concerns the transmission of the techniques by vertical transmission and how vertical transmission is spreading in time and space. These technological knowledges could have been transmitted from master to disciple and thus continuously. If vertical transmission predominates in this process over horizontal transmission then amphorae made in nearby workshops might
70 share more similar traits than amphorae made from farthest workshop. Otherwise whether horizontal transmission is the main transmission in this process the social learning would be transmitted by workers. Then there would not be differences among workshops on the production. The artefact variation can be related to the geographical distance (Björklund et al., 2010; Shennan et al.,
75 2015; Van Strien et al., 2015). In material culture, artefact variation might be

affected by geographical distance where material culture is more similar in close population who interacted each other. In other case, the correlation between both seems not visible due to different factors (Hart, 2012). In our case, we can detect measurable differences among this type of amphorae correlated with the
80 geographical distance.

In this work we have explored the social learning processes associated with amphorae production through a combination of empirical analysis and multivariate methods. The paper is structured as follows. The next section introduces the case study and existing hypotheses, the third section will illustrate about
85 the methods that we have applied to analyze our case study, the next section will deal about the results; and finally we highlight with a discussion about our results.

xavi: by observing que? Por otra parte, el ultimo parrafo de la intro siempre resume el contenido del paper (next section will define the case study and
90 existing hypotheses, the third one will deal with the methods...blablabla
maria: cambiado

2. The amphoric production in Roman Baetica

maria: he quitado las subsection y he aadido el título provisional como me
95 comentaste

Our case study examines the variation of the amphorae production located in *Baetica* (currently Andalusia, south Spain). During the Roman Empire, this ancient province became an important support for the production and distribution of olive oil to the rest of the Empire from Ist to IIIrd centuries Chic (2005);
100 Berni (1998); Remesal (1998)

maria: add una cita más Peacock

For this reason, a large-scale infrastructure of amphorae production was

105 developed around this area to supply the provinces of the Roman Empire with
a huge impact during the supplying of the roman legions in places such as
Britania (Carreras Monfort, 1998) or Germania.

maria: he cambiado campanas militares por legiones romanas :)

110 *Baetica* had also a strong connection thought rivers that allowed developing
an important trade network mostly around the Mediterranean (García Vargas,
2010). maria: he dejado solo mediterraneo pero he puesto mostly :P

As result of this increase, more than 80 pottery workshops were currently lo-
115 cated along the Guadalquivir river and its tributaries 1 However all the sites ex-
amined have currently experimented multiples geographic transformations due
to the anthropic action and the dynamic of the rivers (Enrique y Remesal)xavi:
CITATION NEEDED. Ademas, por que es relevante aqui esto de la antropiza-
cion del territorio?

120 . maria: es relevante porque el paisaje de la baetica cambia bastante desde poca
romana a la actualidad y me gusta matizarlo

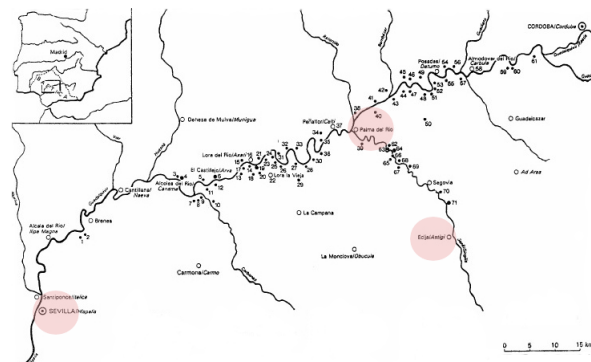


Figure 1: Dressel 20 workshops distribution along the rivers Guadalquivir and Genil

The majority of amphorae produced in this area belong to *Dressel 20* di-
vided into different typologies (Berni Millet, 2008; Martin-Kilcher, 1994). This
125 amphora type was used mostly to transport olive oil for around 300 years in or-

der to satisfy the demand within Roman Empire (Remesal, 1977). In particular, olive oil was a significant product frequently related in different aspect of the roman daily life such as consumption, lighting and hygiene xavi: CITATION NEEDED

130

The importance of this commerce is also showed by the fact that Dressel 20 amphorae production were identified with different marks about its provenance although the meaning of the actors in this process seems not clear maria: (CITATION NEEDED)

135

. In any case, our main question will be related to understand how the amphorae workshops were organized in *Baetica* area and whether it is possible to identify amphorae made in different workshops. Thus, this amphorae production was a particular example of production strategy that experimented few changes around three centuries.

140

maria: FALTA COMPLETAR FINAL

xavi: faltaria acabar esta seccion con una discusion del problema que quieres resolver, incluyendo la pregunta de como se organizaban los talleres, que hipotesis hay y como liga esto con lo que has explicado de social learning.

145

maria: no he incluido las hiptesis de partida porque ya hablo de ellas en la introduccion, tendria que incluirlas aqui tambien?

3. Material and methods

150

xavi: Es mejor si empiezas con el metodo aqui; si no, el lector no entiende de lo que estas hablando.

We analyse a dataset of 470 amphorae collected from 5 different workshops excavated. The workshops were located in Malpica (Palma del Río, Córdoba),

155 Cerro del Belén (Palma del Río, Córdoba) (Díaz Trujillo, 1992), Parlamento
(Sevilla) (García Vargas, 2000), Villaseca (Córdoba)(García Vargas and Morena,
fourthcoming) and Las Delicias (Écija, Sevilla) (Fernández et al., 2001; Mauné
et al., 2014). We created a dataset where were selected 80-100 samples of each
pottery workshops. The choice of these workshops corresponded to several rea-
160 sons. Firstly, the workshops were selected from different spaces in order to
analyse the production patterns depending on the distance of each workshop.
Secondly, the extended chronology of these workshops serves as proxy to exam-
ine changes on the variation shape. In our case, the type Dressel 20 did not
experimented especially visible changes on the production pattern during three
165 centuries.Finally, the workshops selected were open excavated and provided a
large number of materials.

xavi: Mapa?

maria: coming soon

170 maria: he incluido esta subsection antigua field method dentro de esta

Eight different measurements were taken for each amphorae sample of the 5
workshops studied. The measurements were done using different tools: caliber,
square and bevel to take the measurements and profile gauge to draw the pottery
shapes. xavi: no necesitas especificar esto...yo quitaria la ultima frase

175 maria: y así? o la quito?

The measurements were focused on the rim sherds whose fragments were
the most preserved on the archaeological sample. In the case of pottery at-
tributes, rim sherds work as an useful indicator of variability. maria: CITA-

180 TION NEEDED and explain why

Moreover, the measurements were divided into exterior diameter, inside di-
ameter, rim height, rim width, shape width, rim inside height, rim width and
protruding rim (Fig). The method requires a large sample size and for this
reason we focused on rim sherds. Other significative parts such as handles and
185 bases are found in lesser quantities thus compromising the applicability of the

method due to small sample size.

In our study, we have selected five variants according with three centuries (Dressel B: I; Dressel C: I-II; Dressel D: II; Dressel E: III, Dressel F: III. Without important variations in three centuries, the chronology respond to a relative
190 dating obtained by the classification identified on shapes and handles in different studies defined by defined by P. Berni (Berni Millet, 2008) and Martin Kilcher (Martin-Kilcher, 1994) [maria: falta el almeida, illo](#)

All of these variants selected were found in excavations from the proper workshops studied in order to avoid some material which can contaminate the sample.
195 For the proposal of this study, the rest of variants were not taken into account from our study by not having enough material for the analysis.

3.1. Principal Component Analysis

The sample selected were tested using statistical method such as Principal Component Analysis and Discriminant Analysis to explore these metrical
200 differences on the rim sherds.

[xavi: Es mas correcto hablar de "reducir la dimensionalidad" en lugar del numero de variables. Por otra parte, no se si hace falta detallar tanto PCA...mira otros papers similares usando PCA y veras que es tan comun que no hace falta definir mucho \(quizas solo especifica la primera frase, y que es comun en arqueology
205 como las obras citadas abajo\).](#)

[maria: es curioso porque en los papers que he visto sobre arqueometria ni se paran con esto pero en los de arqueologia si, por eso lo hice, debera reducirlo mas ahora?](#)

210 We used Principal Component Analysis (PCA) to reduce the dimensionality of our dataset. This method allows to create a reduced number of *new variables* which contain all the relevant information of the previous variables without losing relevance. The firsts principal components are expressed as the result of the most variance of the all information from the original variables. Moreover
215 the information is expressed as the result of most variation retained in the first

principal components (Jolliffe, 2002; Shennan, 2008). This method is commonly used in archaeology for the study of the variation of material culture (Li et al., 2014; Schillinger et al., 2016b) In our study, this method allows to transform our measurements into PCs and take the firsts PCA with more variability in the dataset.

220 [maria: anadir +biografia y una figura](#)

3.2. Discriminant Linear Analysis

The performed results with PCA were analysed with Lineal Discriminant Analyse (LDA). LDA was used to find significant differences among workshops by the combination among variables obtained for the first principal components. Unlike the PCA, LDA identifies which variables allow to distinguish or discriminate each group and how many variables are necessary to achieve the best combination as possible. In our case, this method allowed to demonstrate the correlation between spatial distance and distance among workshops. LDA was used to explore a better separate training set from the results of the most relevant principal components. LDA can classify the PCs result of the measurements into different groups. We also generate a Confusion Matrix (CM) to able of quantifying the degree of confusion and compare the index of similarity among workshops. CM calculated the probability of success and error of the results. It generates a matrix where higher value are the results of an incorrect classification. The distance generated with the results of DA will be compared with the spatial distance to see if it exists a correlation between morphometric distance and spatial distance.

240 As example, this method has been commonly used in archaeometry (Charlton et al., 2012) [maria: meter citas a cascoporro](#), and particularly for a similar study about the production pottery in *Tarracoenae* (Aguilera, 1998)

4. Results

245 Several multivariate methods such as PCA and LDA were used to quantify the technical differences on the pattern production among workshops. maria: he dejado esta frase a modo introductorio y he quitado las subsection

The analysis of PCA produces a set of values for each variable observed. Variables show how much variability exist in the dataset grouped by each principal components. The results, indicated in the Table, show most variability in the firsts principal components than the rest (mostrar el que ms con el analisis). The most differences were focused on the xavi: Table o Figure?

255 The patterns observed in the first 2 Principal Components were plotted to visualize the degree of variation by isolation among workshops. The results, shown in Fig. 2, suggested than amphorae from closer workshops tend to be more similar than amphorae made in furthest workshops. In particular, the Fig illustrates how the four closest workshops show variation on PC1 (i.e. Belén, 260 Delicias, Villaseca and Malpica) while Parlamento displays a distinctive pattern than the rest of workshops on PC2 values. xavi: que pattern? esto es parte resultados parte discussion, así que quizás deberías unir las 2 secciones

Discriminant Analysis was used to analyze the results obtained from PCA. 265 The results of CM showed than workshops with more troubles to be distinguished such Malpica and Belén shared a minor spatial distance than the rest (see Table 1). Therefore, similar amphorae making techniques processes were strongly correlated with the spatial distance. xavi: distance matrix? maria: que pacha

270

We compared morphometric and spatial distance by performing peer-to-peer analysis between all workshops. We calculated the geographical distance between each site and the distance among pottery measures, calculated using the

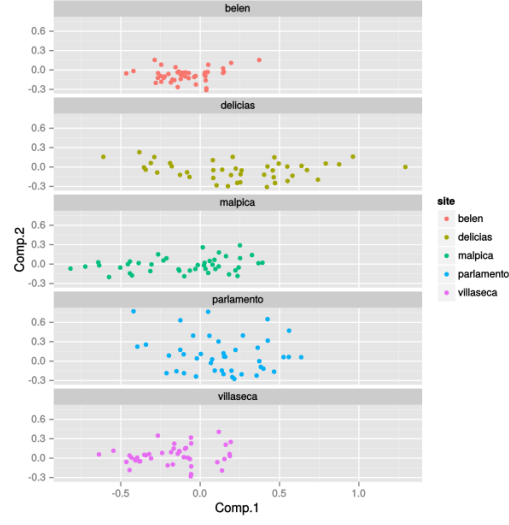


Figure 2: First and Second Principal Components for the analyzed sample

	belen	delicias	malpica	parlamento	villaseca
belen	31	8	14	9	9
delicias	0	22	6	11	1
malpica	5	2	11	2	10
parlamento	4	5	6	15	5
villaseca	3	6	6	6	18

Table 1: Confusion Matrix

previous results. (FIG) shows that the pottery distance is strongly correlated
275 with the spatial distance of workshops.

xavi: Como decia yo quitaria las subsection. Y si hablas de correlacion
deberias cuantificarla (lo miramos cuando este el paper en un segundo draft)

Thus, the results suggest a variability on the making-techniques processes
280 might depend on the spatial distance.

5. Discussion and Conclusion

Differences on the making techniques processes among workshops were identified using empirical method and multivariate analysis. xavi: Esta primera
frase es redundante (si el lector ha llegado aqui ya lo sabe

285 The results show the variability is correlated with spatial distance.

The analysed morphometric traits suggest that the similarity between amphorae decrease with the spatial distance between the workshops where they were produced. As result, amphorae made in nearby workshops with a minor spatial distance share more traits than amphorae made in pottery workshops
290 furthest. In other words, the variability on the making techniques processes between closer workshops was difficult to differentiate. In our case, Malpica and Belén workshops where the geographical proximity are the closest shared more traits in comparison with other workshops (Parlamento and Las Delicias). Thus the probability of interaction between workshops is increasing when the proximity is closest while this likelihood decreases when the possibility of interaction
295 is low.

We have observed than rivers courses could have affected in the transmission factors. In the case of the commerce, rivers and its tributaries played an important role for the transport of goods. The huge demand within Roman Empire
300 and the good conditions for the loading and unloading of products (concierto aceite romano//berni) might have influenced the mode of transmission due to the continuous contact between workshops. xavi: no entiendo esta frase aqui.

que quieres decir?

305 maria: quiero decir que el guadalquivir ofrecia buenas condiciones para el intercambio de materiales o productos

The results suggest also that vertical transmission could be the main cultural mechanism to explain the variability between workshops. The different morphological traits among workshops seem proper of a low contact between
310 potters from others workshops. The evidenced confirms therefore that these techniques traits were transmitted with high fidelity and only with few changes during three centuries. It would mean that the disciples could have remained the making techniques processes in the workshops where they were trained.

By contrast, horizontal transmission doesn't seem to be the most probable
315 process. The continuous contact between potters from different places had generated a more homogeneity in the technical practises. Workshops were sharing the same production techniques. As result, it would generate a social network where potters with the same social learning level worked in different workshops at the same time. Our result suggest a progressive contact with closer work-
320 shop instead. Moreover, the fact that isolation by distance is detected suggests a limited displacement between distant workshops. Thus, vertical transmission would be explained with this observed process. However, the diversity of social learning processes are clearly complex. In other words, the transmission of knowledges between master and disciple did not discard that horizontal trans-
325 mission played an important role in this process as well. It can be a process where this vertical transmission dominated at first in the same workshops but consequently this transmission would be affected by workers who exchanged ideas or workers moving to other workshops.

The combination of empirical analysis with the statistical methods have pro-
330 vided a strong baseline for a better understanding of the amphorae production in the Roman Empirexavi: Esto es el JAS, no hace falta que vendas los metodos cuantitativos :-)

maria: si, pero es un caso particular que yo no he visto en JAS :p o como podra

ponerlo

335 These methods offer also an strong complement to other methods as archaeometry for the characterization of production sites and places of consumption.

We have identified measurable differences in the techniques by observing and we have tested these particularities using multivariate methods. Our analysis provides an useful baseline for the exploration of the social learning processes
340 related with amphora production in the Roman Empire. Hence, the results have lightened to understand the link between social learning and archaeological evidence in a diversity of scenarios.

6. Acknowledgments

Data were collected and performed and analysed in R version 3.2.4. statistical language and implemented with the package MASS. maria: incluir la url
345 con los datos y el cdigo and citation needed

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