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RESEARCH ARTICLE

Symbols in motion: Flexible cultural boundaries and the fast spread of the Neolithic in the western Mediterranean

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Abstract

The rapid diffusion of farming technologies in the western Mediterranean raises questions about the mechanisms that drove the development of intensive contact networks and circulation routes between incoming Neolithic communities. Using a statistical method to analyze a brand-new set of cultural and chronological data, we document the large-scale processes that led to variations between Mediterranean archaeological cultures, and micro-scale processes responsible for the transmission of cultural practices within farming communities. The analysis of two symbolic productions, pottery decorations and personal ornaments, shed light on the complex interactions developed by Early Neolithic farmers in the western Mediterranean area. Pottery decoration diversity correlates with local processes of circulation and exchange, resulting in the emergence and the persistence of stylistic and symbolic boundaries between groups, while personal ornaments reflect extensive networks and the high level of mobility of Early Neolithic farmers. The two symbolic productions express different degrees of cultural interaction that may have facilitated the successful and rapid expansion of early farming societies in the western Mediterranean.

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Introduction

The transition to farming corresponds to the process by which human groups switched from hunting and gathering wild resources to food production based on farming and stockbreeding. In the Near East, sedentism, agriculture and herding progressively took place 12,000 years (y) ago (12ky cal BP). From there, farming technologies spread across Europe from 8,800 until 6,500 y ago (8.8ky–6.5ky cal BP) [1–3]. Several models currently assume significant regional variations in the dispersal process, combining demic diffusion of various magnitudes [4–7] with cultural transmission between incoming farming populations and local foragers [8–11]. Studies also indicate that farming technologies did not spread as a unique package, but rather that material productions followed distinct evolutionary paths with different rates of innovation and diffusion dynamics [12–14]. The cultural geography of Europe appeared completely

reshaped by the diffusion of the Neolithic, due to intense and repeated inter-group interactions and the circulation of individuals, ideas and techniques [15–17].

Radiocarbon dates indicate that the coastal spread of the Neolithic in the western Mediterranean of Europe took place at a much faster rate (above 5 km.y⁻¹) than in Central Europe [18]. The role of long-distance maritime travel combined with demic expansion and interactions with local hunter-gatherers best explains the rapid spread of farming technologies in this area of Europe [18,19]. Cultural data also identify the Mediterranean area as a hotspot of cultural diversity, where early farming populations played an influential role in the shaping of the European cultural geography [20].

However, questions persist on the relations established between the successive incoming farming populations and the role their interactions had on the gradual assimilation of the local foraging communities. To tackle this issue, we developed a statistical approach to conjointly document the processes that led to variations between Mediterranean archaeological cultures and the micro-scale processes responsible for the transmission of cultural practices within archaeological cultures.

By examining two categories of material culture, namely pottery decorative techniques and personal ornaments, we explore spatial and temporal variation in Early Neolithic cultural diversity in western Mediterranean Europe (8ky–6.5ky cal BP).

Both pottery decorative techniques and personal ornaments are intended to be seen and to transmit various symbolic messages. Pottery production and design represent a valuable social medium to signal membership and individual identity and aptitudes [21–24]. Exchange networks and social relations established between individuals and communities result in the spatial patterning of the pottery design distributions [25–27]. Personal ornaments also represent a visual message intended to mediate many social conventions related to individual and group identity [28]. Personal ornaments are used for social transactions [29,30], rituals [31] and the transmission of social memories [32,33], and to display social status within communities [34].

These two categories of production have the advantage of widespread dissemination over Europe during the transition to farming, and are characterized by a wide range of morphological, typological and stylistic traits. Their preservation in the archaeological record and their extensive analysis allow us to investigate spatial patterning and diffusion processes [17,20,35–37]. Pottery decorations and personal ornaments also fulfill exclusively symbolic functions appropriate to detecting cultural affinities between populations and patterns of cultural change through time [38–40].

Pottery attributes are classically used to define the cultural affiliation of archaeological assemblages [26,41] as well as investigate social dynamics [23,24] and characterize past cultural networks [42,43]. The ability of personal ornaments to characterize the circulation networks [44,45], social organization [46–48] and cultural geography of past populations has also been demonstrated [20,35,36].

The transfer of cultural traits within and between past communities has long been the subject of investigation, and mechanisms at work in the processes of cultural transmission and diversification are studied in depth through the application of evolutionary biology models to the transmission of cultural traits [49,50]. Cultural evolution theories state that the emergence, persistence and loss of cultural traits over time are impacted by cultural selection processes, selection bias and cultural drift [39,40,51]. Analytical methods applied to cultural evolution have contributed to the documentation of variation patterns in the archaeological record and the various transmission mechanisms responsible for similarities and differences among groups in space and time [14,52–55].

Our study relies on this approach. Our sample is constituted of cultural and chronological data recorded from 52 archaeological occupations covering Italy, France and Spain, and

spanning over 1,300 years (worksheets A and B in [S1 Dataset](#), Text A and Figure A in [S1 File](#)). The chronological dataset is built on 114 radiocarbon dates including 44 new direct datings of key occupations (worksheet H in [S1 Dataset](#)). Using a typological classification system that we developed for pottery decorative techniques [56,57] and personal ornaments [20,58], we submitted the data (worksheets D and F in [S1 Dataset](#))—formatted as cultural, chronological and geographic distance matrices—to a series of multivariate analyses.

Materials and methods

The method we developed aims to answer several questions: (1) What mechanisms of cultural transmission generated variations in the two symbolic productions? (2) Did they operate equally in time and space and (3) at identical speed? (4) Did they create sharply structured cultures or, conversely, did they generate high intra-cultural variability?

Pottery

Decorated pottery is widely used to construct and compare chronologies in many archaeological contexts [41]. Pottery decorations, both abstract and figurative, constitute conventionalized artistic designs used to mediate many symbolic messages within societies [59]. Decorations may have religious intent related to rituals [60,61], or may depict conventional social narratives [62] related to folklore or even everyday experiences [63]. By working exclusively on decorative techniques, we minimize bias from factors relating to the original function of the assemblages (e.g. cooking or storage) potentially conditioning the shaping techniques and treatment surfaces [64]. Pottery decorations also have the advantage of being a visual proxy used to display individual skills and abilities [21]. The transmission of skills within a community tends to maintain decorative traditions [65], but efforts from crafters to distinguish themselves from each other also initiate changes in decorative attribute diversity in the long run [66]. The visual aspect of decorative attributes may vary depending on the tools used to decorate the artifacts, the gesture used to apply the tools to the surface of the pottery and eventually the morphology of the decoration itself. Each archaeological assemblage included in the database is described with 13 quantitative variables regarding these decorative attributes (worksheet E in [S1 Dataset](#), Figure B in [S1 File](#)).

By considering the relative proportion of decorative technique types within a stratigraphy, it is possible to observe the introduction, growing usage and demise of specific technological and decorative traits [43,57]. Considering solely qualitative data prevents the observation of diachronic and synchronic variability that may be perceptible at different geographic scales [57]. To avoid the limitations of qualitative sampling, each variable was counted from each occupation included in the database.

We analyzed decorative techniques of pottery from 39 Early Neolithic occupations in western Mediterranean Europe (worksheets A, D and E in [S1 Dataset](#)).

The pottery remains included in the database are mostly of local origin [42], but a small number were imported from 7 km to more than 100 km away [42,67]. Both local and imported potteries are discarded items left in domestic structures by Neolithic farmers, suggesting that they were used for daily activities [68,69]. Geographic coordinates, cultural affiliation and corresponding time span of existence (worksheet H in [S1 Dataset](#), Text A and B in [S1 File](#)) are documented for each archaeological assemblage. Our sample covers seven archaeological cultures attributed to early farming communities spanning a temporal range of ca. 1,500 years (ca. 7950–6450 cal BP).

Personal ornaments

Body ornaments are central to the creation of social and self-identity [70]. Their various associations and their display on the body contribute to negotiating identities and unifying or

distinguishing communities [28,71]. Because the primary role of personal ornamentation is to be seen in order to transmit symbolic messages, the most important characteristics of beads are those whose modification will distort their visual impact [34,72–74].

The typology of personal ornaments in this study was established following the method of Rigaud et al. (2015). It takes into account cross-cultural studies on the classification of beads and criteria used to classify archaeological artifacts [75,76]. Discrete bead types were created with reference to raw material, morphology, system of suspension (e.g. perforation or groove), size, section and profile. In the case of animal teeth, we also considered anatomical and species identification (Figure C in [S1 File](#)).

The amount and types of ornaments recovered at an archaeological site depend on the site function (e.g. domestic or funeral) and the excavation methods. Systematic sieving of the sediment with small mesh grids can, for example, significantly increase the number of small beads recovered [77]. Since, due to the above reasons, proportions of ornaments recovered at archaeological sites cannot be considered representative of the importance attributed to specific ornament types by foraging and farming populations, in our analyses we only used the presence or absence of data.

Presence or absence of bead types was coded as “1” or “0” respectively, to produce a matrix of 58 archaeological occupations coded across 88 binary traits (worksheets B, F and G in [S1 Dataset](#)). Geographic coordinates, cultural affiliation and corresponding time span of existence (worksheet H in [S1 Dataset](#) and Texts A and B in [S1 File](#)) are documented for each archaeological assemblage. Our sample covers eight archaeological cultures attributed to early farming communities spanning a temporal range of ca. 1,500 years (ca. 7950~6450 cal BP).

Unit of analysis

Each archaeological occupation is assigned to one of the six Mediterranean Early Neolithic archaeological cultures. Archaeological cultures are defined as a system of transmission of social information that materializes population-level processes [78]. They represent geographic and chronological units characterized by archaeological occupations associated to durable material culture generated by consistent transmission across generations [49,79]. Archaeological cultures cannot be compared to cultural groups as observed in the ethnographic record, but they represent the unit of analysis commonly used for diachronic archaeological studies [14,80–82]. Early Neolithic archaeological cultures considered in this analysis are defined in the literature according to lithic technology, settlement pattern, ceramic productions and level of admixture with local foraging communities (Text A in [S1 File](#) [9,83,84]).

Cultural diversity

We first quantified how archaeological sites differed in pottery and personal ornament attributes by using two different distance indices. The Jaccard distance index [85] is appropriate for presence/absence data [86] and has been used for calculating pairwise site differences according to their bead-type diversity (worksheet L in [S1 Dataset](#)). The Bray–Curtis distance index [87] is appropriate for count data [88] and has been used for calculating pairwise site differences according to their pottery attributes (worksheet I in [S1 Dataset](#)).

Relationships among archaeological cultures and sites

Phylogenetic methods are effective in testing hypotheses about the role of cultural transmission in shaping material culture diversity [89,90]. However, the application of phylogenetic tools directly borrowed from evolutionary biology in order to explore cultural evolution is somewhat flawed because cultural traits are transmitted through time from generation to

generation (vertical transmission) but also between neighboring populations (horizontal transmission) [91,92]. The NeighborNet technique explores evolutionary relationships characterized by potentially high levels of lateral transfer that are not perceivable through other network-based methods [93]. We used the NeighborNet method [94] to visualize the relationships among the archaeological sites and cultures. The analysis determines conflicts within the data as represented by reticulations or joining among branches. From the shape of the NeighborNet network, it is possible to infer the level of borrowing and convergence that occurred between the different archaeological sites and cultures. The analysis was performed in Splitstree4 using standard settings [95]. The Delta score and the Q-residual [96] are two methods for calculating the level of reticulation in the network [97]. The two scores range from 0 to 1 with increasing conflicting signal.

Isolation by distance

Understanding how isolation facilitates the development of behavioral barriers to cultural flow requires incorporating chronological and geographical distances into analyses of cultural transmission and differentiation [14,20,98]. The isolation-by-geographic-distance model predicts a positive relationship between increased cultural differentiation and spatial/temporal distance. To account for the effect of spatial and temporal distances on cultural diversity, correlation between cultural, geographic and chronologic distance matrices was calculated using a partial Mantel test [99]. The partial Mantel test has been implemented in the *vegan* [100] and *ecodist* [101] packages in R (R Core Team, 2013) using 1,000 random permutations of the data. Great-circle (spatial) distance has been calculated from the latitude and longitude data (R command published by Shennan et al., 2015, worksheets J and M in [S1 Dataset](#)). We used the Euclidean distance between earliest and latest dates for each archaeological culture (worksheets K and N in [S1 Dataset](#)). As the Mantel test results could be biased by the non-linear relationships between distances, we performed analyses using both the original untransformed and log-transformed distance matrices [102–104].

Cultural geography

The various transmission processes and differential impact of the isolation by distance on the two productions may lead to distinct geographic patterns of diffusion. Spatial interpolation is one of the GIS processing methods used for the visualization of variations in the data, data structures and static data patterns [105–107].

Pairwise cultural distance calculated between sites was entered into a Principal Coordinates Analysis (PCoA) performed in the software PAST [108] to identify and plot similarities in terms of bead type and pottery decoration diversity between sites (Figure D in [S1 File](#)). Mapping of the two first axes of the PCoA was performed by using the Inverse Distance Weighting (IDW) interpolation method [109] run through the software QGIS 2.6.1. The based map was created from ETOPO1 Global Relief Model data (<http://www.ngdc.noaa.gov/mgg/global/>) [110].

Cultural structure

Variation between archaeological cultures documented by the analyses conducted in this study may hide a higher and significant variation within cultures. The AMOVA framework [111] provides a means of exploring how variability in productions is structured within and between cultures [14,112,113]. The result is expressed by the Φ_{ST} statistic, which represents to what extent the two productions are characterized by distinct archaeological cultures (worksheet C in [S1 Dataset](#)). The analysis was performed on the pottery decoration and personal ornament

attributes to calculate the cultural diversity within and between archaeological cultures. The Φ_{ST} statistic was calculated with a permutation test (1,000 iterations) using the pegas package in R [114].

Inter-culture distances

The differential success of cultural innovations contributes to material culture variation [115]. Cultural choices and mechanisms similar to natural selection may conjointly act in the shaping of cultural diversity [40]. The pace of the emergence and preservation of new cultural traits may then slow down or accelerate cultural evolution. Possible selection process was investigated by verifying if the two sets of cultural data changed at different rates [40,116]. The central tendency (mean and median) of the ornament and pottery inter-culture distance matrices was measured and two conservative nonparametric tests were undertaken: a Wilcoxon signed-rank test for paired cultures using the MASS package in R [117] and a Sign test for paired cultures using the BSDA package in R [118]. To compare the rate of evolution of the two material productions, the two tests were performed on a subset based on the seven cultures common to both datasets.

Results

Relationships among cultures and archaeological sites

The NeighborNet analysis (Fig 1) processed with the archaeological sites as the unit of analysis demonstrates that ornament and pottery data do not appear to be tree-like and display reticulations. The two networks show differences in delta score and q-residual (delta score for the ornament network: 0.30, q-residual: 0.007; delta score for the pottery network: 0.33, q-residual: 0.021). The delta score indicates a conflicting signal in the two productions with a moderately tree-like tendency for the two overall patterns. The q-residual, and to a lesser extent the delta score, suggest that reticulation is more common in the pottery data than in the ornament data. Those values are agree with previous similar studies on linguistic phylogeny [96,119,120]. The NeighborNet graph obtained for pottery data (Fig 1A) does not show clear splits, but the archaeological occupations are to some extent organized according to their chrono-cultural

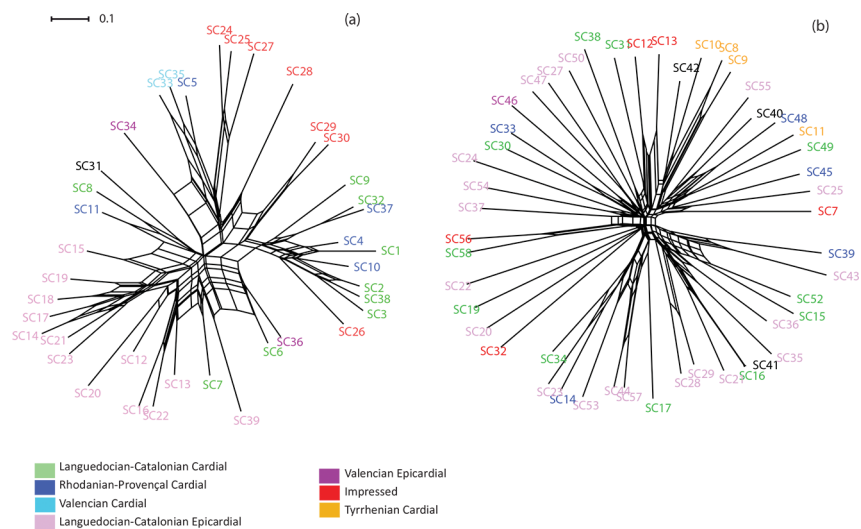


Fig 1. NeighborNet tree of the Early Neolithic archaeological sites identified in the western Mediterranean region: a) pottery data, b) personal ornament data. Archaeological sites are color-coded according to their cultural attribution.

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attributions. The most recent western occupations (in pink) are grouped on the left of the graph, and the earliest eastern occupations (in red) on the right. The other archaeological occupations belong to several other intermediate archaeological cultures and randomly cluster between the two extremes sets of occupations. The NeighborNet graph obtained for the ornament data (Fig 1B) does not show clear geographic or chronological clustering.

Correlation in space and time

Correlations between the cultural and the spatial and temporal distances show different results for the ornament and pottery data (Table 1). Variation in the personal ornaments shows a statistically significant correlation with the geographic matrices ($p < 0.01$), with approximately 15 to 25% of the variance explained by geography. The temporal distance between archaeological sites does not significantly contribute to the variance. On the other hand, pottery data show significant correlation for distance in space and time: approximately 23 to 28% of the variance is explained by the geography ($p < 0.01$) and 27 to 37% of the variance is explained by the chronology ($p < 0.01$). Log-transformed distances showed similar results for both datasets.

These values are clearly higher than those observed in similar analyses of genetic distances between individuals across Europe [121,122], folktale and linguistic distances [112] and stylistic distances between other sets of archaeological data [14].

Cultural geography

The maps of interpolated pottery decorative techniques and bead-type diversities throughout the western Mediterranean show the highest interpolated values in southern Italy (Fig 2B). Hotspots restricted to the east of the Rhône Valley in southern France and eastern Iberia are also visible on the map of bead-type association diversity. Conversely, southern France and eastern Iberia are characterized by lower interpolated values on the map of pottery decorative techniques diversity (Fig 2A).

Cultural structure

The Φ_{ST} statistic indicates that both ornaments and pottery show a statistically significant cultural structure, but pottery shows a higher score: $\Phi_{ST} = 0.236$ for pottery, and $\Phi_{ST} = 0.05$ for the ornament data, both with $p < 0.001$. The higher score obtained for pottery data indicates that pottery decorative techniques are more variable between archaeological cultures than bead-type associations.

Table 1. Results of the partial Mantel test.

Variable	Pottery		Ornaments	
	R2	p	R2	p
Geography, holding time	0.238	0.003	0.151	0.009
Geography, holding log(time)	0.302	0.001	0.161	0.008
Log(geography), holding time	0.254	0.001	0.25	0.001
Log(geography), holding log(time)	0.284	0.001	0.259	0.001
Time, holding geography	0.336	0.001	0.021	0.35
Time, holding log(geography)	0.373	0.001	-0.007	0.562
Log(time), holding geography	0.277	0.001	0.018	0.321
Log(time), holding log(geography)	0.293	0.001	-0.043	0.88

<https://doi.org/10.1371/journal.pone.0196488.t001>

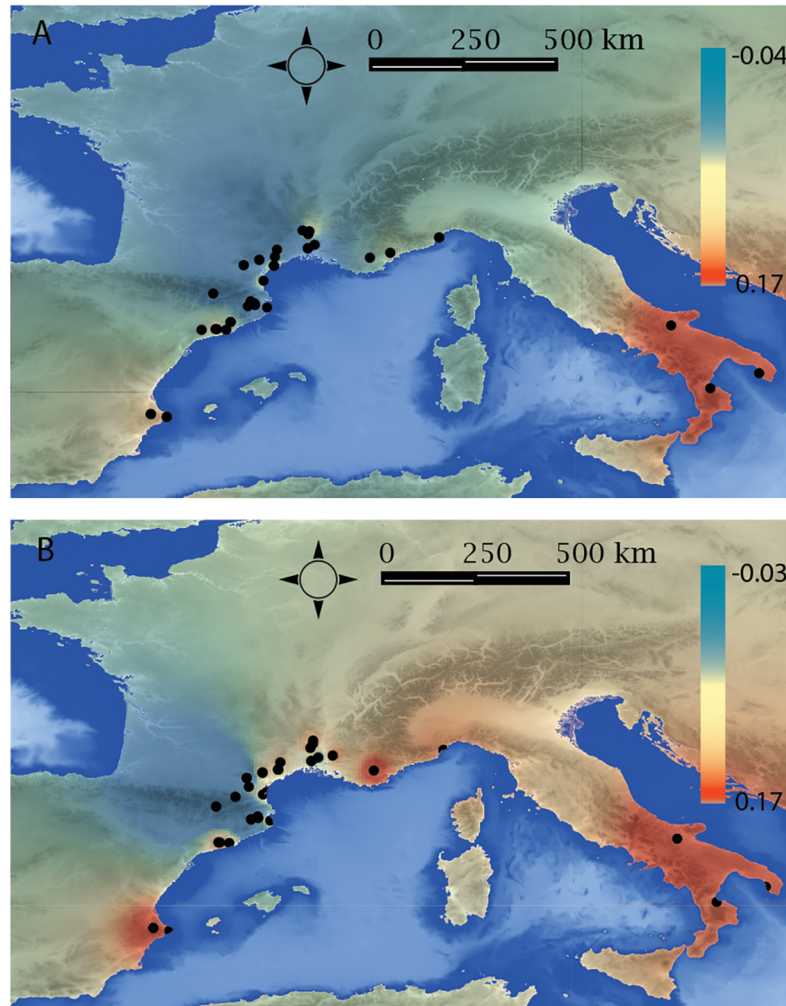


Fig 2. Mean Inverse Distance Weighting (IDW) interpolation of the first two axes of the Principal Coordinates Analysis (Figure D in S1 File). Diversity of the pottery attributes (A) and bead-type associations (B) express two different cultural geographies. Maps were made by S. R. using the software QGIS 2.6.1 and Etopo1 Digital Elevation Model [110].

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Inter-culture distances

The two tests do not indicate statistically significant differences between the paired culture distances observed in the pottery data compared to those seen in the ornament data (Wilcoxon signed-rank test: $V = 97$, $p\text{-value} = 0.539$; Sign test: $s = 9$, $p\text{-value} = 0.663$). The measures of central tendency for the ornament data (mean = 0.83; median = 0.84) are very close to those observed for the pottery ones (mean = 0.76; median = 0.81, Fig 3).

Discussion

The NeighborNet analysis demonstrates that the cultural data do not appear to be tree-like. The reticulations show conflicting signals that might be caused by hybridization, coalescence and noise in the data [123]. In the case of cultural data, even if noise in the data cannot be excluded, the lateral flow of cultural traits is generally proposed to explain conflicting signals [112,124,125]. Lateral transmissions likely also acted in the past and played a role in the

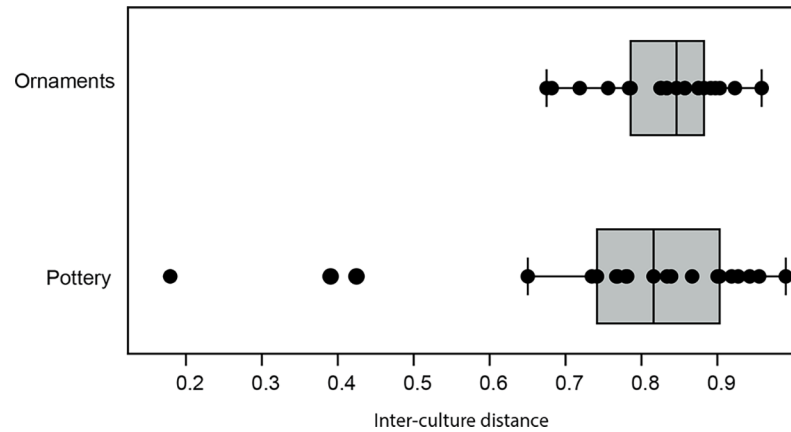


Fig 3. Box plot of the inter-culture distances for the ornament and pottery data.

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shaping of pottery decorative techniques and personal ornament diversity within early farming cultures. The different delta scores, q-residuals and clusters obtained for pottery and ornament attributes indicate separated and non-linear evolutionary trajectories for the two categories of material cultures. Studies on modern populations have shown that cultural traits and productions with a similar range of delta scores (between 0.29 and 0.41) were inclined to circulate and borrow, with increasing levels of conservatism toward the lower scores [96,125,126]. The higher delta score, and even higher q-residual, obtained for the pottery NeighborNet analysis indicates that pottery attributes were more inclined to circulate and be exchanged than personal ornaments.

The higher coefficient correlation obtained between pottery and geographic distance indicates that decorative attributes related to pottery decoration tools and techniques tend to be more distinct with increasing geographical distance between archaeological sites than bead-type associations. The impact of spatial distance on the pottery attributes indicates that the circulation and borrowing of cultural traits predominantly occurred at local level. Conversely, the capacity of ornaments to be diffused over large distances is confirmed by the lower correlation coefficient calculated between geographic distance and bead-type associations. The Mantel correlation indicates that less than 40% of the variance of the two productions is explained by geographic distance. These correlations imply that isolation by distance (IBD) affected the pottery decorative techniques and personal ornament diversity conjointly with other evolutionary mechanisms. Few other attempts have been made to test the effect of IBD on early archaeological productions [14,20,37]. Many scenarios have to be tested to better understand the impact of geographic distance on archaeological assemblage dissimilarity, including mobility (foraging versus sedentary societies), the effect of latitude and environment and the type of productions (functional or symbolic).

Distance in time also significantly predicts pottery attribute similarity, but does not contribute to an explanation of personal ornament similarity. The distance in time between archaeological sites is calculated from direct absolute radiocarbon dates (worksheet H in [S1 Dataset](#)), implying that the influence of time in the diversity of pottery decorative techniques does not simply reflect the use of potteries in the identification of archaeological cultures. Ethnographic studies indicate that pottery decorations especially fluctuate over generations and territories because they are often used by crafters to signal and differentiate their individual skills relatively to other group members [21,65,127,128]. Similar behavior may have existed within Mediterranean Early farming communities. The mastery of pottery manufacture and decoration also requires complex learning processes that contribute to the perpetuation of traditions over

time [65,127]. The influential role of distance in time and space in pottery decoration corresponds to frequent cultural transmissions among individuals geographically close to each other. These small-scale transmissions have resulted in enduring stylistic frontiers between groups, largely visible in the archaeological record [37].

The absence of correlation between ornament attributes and temporal distance and the lower delta score and q-residual show the substantial stability and persistence of the bead-type associations, indicating more conservative traditions. The endurance of bead-type associations suggests that specific transmission processes favored the reliable reproducibility through time of symbolic codes expressed by personal ornaments. The exact transmission of the techniques and symbols involved in the crafting of personal ornamentations suggests that few specialized crafters were in charge of bead manufacture within early farming communities. Preservation of bead traditions also required the long-term maintenance of circulation networks for exogenous raw material supply [20,129].

The maps of interpolated pottery decoration and bead-type diversities show different cultural geographies related to the distinct cultural trajectories followed by the two symbolic productions.

As attested by the AMOVA analysis results, pottery attributes are more variable than bead-type associations between archaeological cultures. This result echoes the classic use of pottery shape and decoration to define the cultural affiliation of archaeological assemblages [26,41,130]. Bead-type association diversity is extremely low between the archaeological cultures. This result indicates that bead-type association diversity does not follow the chrono-cultural seriation of the Early Neolithic as defined by archaeologists according to other material and economic proxies (Text A in [S1 File](#)). Discrepancies between personal ornament assemblages and classic chrono-cultural frameworks has already been evidenced at other scales and for other archaeological contexts [20,35,36,131,132]. Traditionally, personal ornaments can have many different functions (e.g. amulets or markers of gender, social/biological age, wealth or social status) within communities [133,134]. The sharing of common symbolic messages, communicated by position and association of bead types on the body, contributes toward increasing the feeling of cohesion and membership [28] and constitutes a powerful social medium within communities [135,136]. The high level of variation of bead-type associations observed within Mediterranean early farming archaeological cultures indicates that personal ornaments were used to express a wide range of symbolic messages and fulfilled more diversified functions than pottery decorative techniques. The extreme variability of the bead-type associations likely reflects multiple individualistic styles probably related to the various social statuses that may have existed within the first farming communities.

Thus, while bead-type diversity attests to the intense circulation of ideas and individuals, the space and time diversity of pottery decorative techniques should be seen as evidence of group resilience to such permeability.

The Wilcoxon signed-rank and Sign tests do not show significant differences between intercultural distances calculated for pottery decoration and personal ornament attributes. Transmission mechanisms identified by our analyses did not differentially impact the cultural rate of change in one production relative to the other. Pottery decorative techniques and bead-type associations selected for symbolization were likely not directly adaptive. They were rather dedicated to generating and strengthening personal and group identities [137,138], and the fixation or loss of cultural traits related to their productions were affected by similar selection regimes.

Conclusions

Our results shed light on the cultural mechanisms responsible for the complex cultural geography of the western Mediterranean during the transition to farming. Pottery decorations

participated in restrained networks in which geographical proximity and local processes of transmission played an influential role. Bead-type associations were used to tell multiple stories about social identities, were especially resistant to change and are characterized by a greater stability through time and space. The high level of cultural connection between the early farming communities favored movement, interaction and exploration and likely represented a successful strategy for their rapid expansion in the western Mediterranean. Cultural boundaries persisted despite a flow of individuals and symbolic transfer across them.

Genetic studies indicate that the last foragers and the first farmers developed social and cultural relationships more closely tied than previously indicated through components of the material culture [139]. Biological data and chronological models support a pattern of diffusion implying geographically discontinuous contacts between local foragers and incoming farmers, but repeated in time [9,140,141]. This process of diffusion conjointly occurred with changes in material culture, including pottery decorations and personal ornaments. Pottery production represents a technological innovation mostly associated with the Neolithic way of life in the western Mediterranean. Pottery decorations were likely particularly sensitive to interactions, leading to their high variability in time and space in order to reinforce group membership. Conversely, personal ornaments were less inclined to change in space and time. Their production by both local foragers and incoming farmers implies different cultural readjustments that led to a completely different pattern of variation in time and space. The preservation of the foragers' personal ornament styles (and likely also meanings) within emerging farming communities [20,58] has probably contributed to the maintenance of their stability through time and space.

The two symbolic productions appear as a polythetic set of cultural behaviors dedicated to mediating early farmer identities in many ways, and personal ornaments likely reflected the most entrenched and lasting facets of farmers' ethnicity.

Supporting information

S1 Dataset. Database of the archaeological sites, layers, variables and radiocarbon dates used in the analysis.

(XLSX)

S1 File. Method and criteria used for the design of the bead-type, pottery decoration and radiocarbon date databases.

(PDF)

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References

1. Ammerman AJ, Cavalli-Sforza LL. The Neolithic transition and the genetics of population in Europe. Princeton: Princeton University Press; 1984.
2. Bar-Yosef O. Guest editorial: East to West—Agricultural origins and dispersal into Europe. *Curr Anthropol*. 2004; 45: S1–S3.
3. Özdoğan M. Archaeological Evidence on the Westward Expansion of Farming Communities from Eastern Anatolia to the Aegean and the Balkans. *Curr Anthropol*. 2011; 52: S415–S430. <https://doi.org/10.1086/658895>
4. Bocquet-Appel J-P. Explaining the Neolithic Demographic Transition. In: Bocquet-Appel J-P, Bar-Yosef O, editors. *The Neolithic Demographic Transition and its Consequences*. Springer Netherlands; 2008. pp. 35–55. Available: http://dx.doi.org/10.1007/978-1-4020-8539-0_3
5. Fernández E, Pérez-Pérez A, Gamba C, Prats E, Cuesta P, Anfruns J, et al. Ancient DNA Analysis of 8000 B.C. Near Eastern Farmers Supports an Early Neolithic Pioneer Maritime Colonization of Mainland Europe through Cyprus and the Aegean Islands. *PLoS Genet*. 2014; 10: e1004401. <https://doi.org/10.1371/journal.pgen.1004401> PMID: 24901650
6. Olalde I, Schroeder H, Sandoval-Velasco M, Vinner L, Lobón I, Ramirez O, et al. A Common Genetic Origin for Early Farmers from Mediterranean Cardial and Central European LBK Cultures. *Mol Biol Evol*. 2015; Available: <http://mbe.oxfordjournals.org/content/early/2015/09/23/molbev.msv181.abstract>
7. von Cramon-Taubadel N, Pinhasi R. Craniometric data support a mosaic model of demic and cultural Neolithic diffusion to outlying regions of Europe. *Proc R Soc B Biol Sci*. 2011; Available: <http://rspb.royalsocietypublishing.org/content/early/2011/02/17/rspb.2010.2678.abstract>
8. García-Martínez de Lagrán I, Garrido-Pena R, Rojo-Guerra MA, Tejedor-Rodríguez C. Historia de un debate: planteamientos teóricos sobre la neolitización de Europa y la Península Ibérica. In: Rojo-Guerra MA, Garrido Pena R, Garcia-Martinez-de-Lagran I, editors. *Historia de un debate: planteamientos teóricos sobre la neolitización de Europa y la Península Ibérica*. Editorial Cátedra. Madrid; 2012. pp. 71–94.
9. Guilaine J, Manen C. From Mesolithic to early Neolithic in the western Mediterranean. In: Whittle A, Cummings V, editors. *Going over: The Mesolithic-Neolithic Transition in the North-West Europe*. London: Proceedings of the British Academy; 2007. pp. 21–51.
10. Le Roy M, Rivollat M, Mendisco F, Pemonge M-H, Coutelier C, Couture C, et al. Distinct ancestries for similar funerary practices? A GIS analysis comparing funerary, osteological and aDNA data from the Middle Neolithic necropolis Gurgy “Les Noisats” (Yonne, France). *J Archaeol Sci*. 2016; 73: 45–54. <https://doi.org/10.1016/j.jas.2016.07.003>
11. Rigaud S. Pratiques ornementales des premières communautés agro-pastorales de Bavière (Allemagne): Intégration? Acculturation? Convergence? Nouveaux apports de la nécropole de Essensbach-Ammerbreite. *Anthropol Int J Hum Divers Evol*. 2014; 1–22.

12. Cilingiroğlu Ç. The concept of “Neolithic package”: considering its meaning and applicability. *Doc Praehist.* 2005; 32: 1–13.
13. Guilaine J. *De la vague à la tombe. La conquête néolithique de la Méditerranée.* Paris: Seuil; 2003.
14. Shennan SJ, Crema ER, Kerig T. Isolation-by-distance, homophily, and “core” vs. “package” cultural evolution models in Neolithic Europe. *Evol Hum Behav.* 2015; 103–109. <https://doi.org/10.1016/j.evolhumbehav.2014.09.006>
15. Fowler C, Harding J, Hofmann D. *The Oxford Handbook of Neolithic Europe.* Oxford: Oxford Handbooks; 2015.
16. Zvelebil M. The Many Origins of the LBK. In: Lukes A, Zvelebil M, editors. *LBK Dialogues Studies in the formation of the Linear Pottery Culture.* BAR International Series; 2004. pp. 182–205.
17. Bernabeu Aubán J, Lozano S, Pardo-Gordó S. Iberian Neolithic Networks: The Rise and Fall of the Cardial World. *Front Digit Humanit.* 2017; 4: 7. <https://doi.org/10.3389/fdigh.2017.00007>
18. Isern N, Zilhão J, Fort J, Ammerman AJ. Modeling the role of voyaging in the coastal spread of the Early Neolithic in the West Mediterranean. *Proc Natl Acad Sci.* 2017; 114: 897–902. <https://doi.org/10.1073/pnas.1613413114> PMID: 28096413
19. Fort J. Synthesis between demic and cultural diffusion in the Neolithic transition in Europe. *Proc Natl Acad Sci.* 2012; 109: 18669–18673. <https://doi.org/10.1073/pnas.1200662109> PMID: 23112147
20. Rigaud S, d’Errico F, Vanhaeren M. Ornaments Reveal Resistance of North European Cultures to the Spread of Farming. *PLoS ONE.* 2015; 10: e0121166. <https://doi.org/10.1371/journal.pone.0121166> PMID: 25853888
21. Hart JP, Engelbrecht W. Northern Iroquoian Ethnic Evolution: A Social Network Analysis. *J Archaeol Method Theory.* 2012; 19: 322–349. <https://doi.org/10.1007/s10816-011-9116-1>
22. Bliege Bird R, Smith EA. Signaling Theory, Strategic Interaction, and Symbolic Capital. *Curr Anthropol.* 2005; 46: 221–248. <https://doi.org/10.1086/427115>
23. Dietler M, Herbich I. Habitus, Techniques, Style: An Integrated Approach to the Social Understanding of Material Culture and Boundaries. In: Stark M, editor. *Archaeology of social boundaries.* Washington D.C.: Smithsonian Institution press; 1998. pp. 232–263.
24. Roux V. A Dynamic Systems Framework for Studying Technological Change: Application to the Emergence of the Potter’s Wheel in the Southern Levant. *J Archaeol Method Theory.* 2003; 10: 1–30.
25. Stark MT. From sibling to suki: Social relations and spatial proximity in Kalinga pottery exchange. *J Anthropol Archaeol.* 1992; 11: 137–151. [https://doi.org/10.1016/0278-4165\(92\)90018-7](https://doi.org/10.1016/0278-4165(92)90018-7)
26. Shepard AO. *Ceramic for the Archaeologist.* Washington D.C.: Carnegie Institution of Washington; 1956.
27. Hart JP, Shafie T, Birch J, Dermarkar S, Williamson RF. Nation Building and Social Signaling in Southern Ontario: A.D. 1350–1650. *PLOS ONE.* 2016; 11: e0156178. <https://doi.org/10.1371/journal.pone.0156178> PMID: 27223890
28. Sanders JM. Ethnic Boundaries and Identity in Plural Societies. *Annu Rev Sociol.* 2002; 28: 327–357.
29. Dubbeldam LFB. The Devaluation of the Kapauku-Cowrie as a Factor of Social Disintegration. *Am Anthropol.* 1964; 66: 293–303.
30. Ogundiran A. Of Small Things Remembered: Beads, Cowries, and Cultural Translations of the Atlantic Experience in Yorubaland. *Int J Afr Hist Stud.* 2002; 35: 427–457. <https://doi.org/10.2307/3097620>
31. Sharp L. Ritual life and economics of the Yir-Yoront of Cape York Peninsula 15. *Oceania.* 1934; 5: 19–42. <https://doi.org/10.1002/j.1834-4461.1934.tb00129.x>
32. Casella EC. “That’s Just a Family Thing, You Know”: Memory, Community Kinship, and Social Belonging in the Hagg Cottages of Cheshire, North-West England. *Int J Hist Archaeol.* 2012; 16: 284–299. <https://doi.org/10.1007/s10761-012-0179-9>
33. Casella Colin E, Fowler C. *The Archaeology of Plural and Changing Identities: Beyond Identification.* Springer US. 2005.
34. Kassam A. Traditional ornament: Some general observations. *Kenya Past Present.* 1988; 20: 11–16.
35. Newell RR, Kielman D, Constandse-Westermann TS, van der Sanden WAB, Van Gijn A. *An Inquiry Into the Ethnic Resolution of Mesolithic Regional Groups: The Study of Their Decorative Ornaments in Time and Space.* 1990.
36. Vanhaeren M, d’Errico F. Aurignacian ethno-linguistic geography of Europe revealed by personal ornaments. *J Archaeol Sci.* 2006; 33: 1–24.
37. Bernabeu Aubán J, Manen C, Pardo-Gordó S. Spatial and Temporal Diversity During the Neolithic Spread in the Western Mediterranean: The First Pottery Productions. In: García-Puchol O, Salazar-

- García DC, editors. *Times of Neolithic Transition along the Western Mediterranean*. Cham: Springer International Publishing; 2017. pp. 373–397. https://doi.org/10.1007/978-3-319-52939-4_14
38. Dunnell RC. *Style and Function: A Fundamental Dichotomy*. *Am Antiq*. 1978; 43: 192–202.
 39. Lipo C, Madsen M. Neutrality, “style,” and drift: Building methods for studying cultural transmission in the archaeological record. In: Hurt TD, Rakita GFM, editors. *Style and Function: Conceptual Issues in Evolutionary Archaeology*. Westport, Connecticut: Bergin and Garvey; 2000. pp. 91–118.
 40. Rogers DS, Ehrlich PR. Natural selection and cultural rates of change. *Proc Natl Acad Sci*. 2008; 105: 3416–3420. <https://doi.org/10.1073/pnas.0711802105> PMID: 18287028
 41. Childe VG. *L'Europe préhistorique: les premières sociétés européennes*. Paris: Payot; 1962.
 42. Manen C, Convertini F. Neolithization of the Western Mediterranean: Pottery productions, circulation and recombination. In: Borrell M, Borrell Tena F, Bosch Argilagós J, Clop Garcia X, Molist Montaña M, editors. *Actes: Xarxes al Neolític: Congrés Internacional: Xarxes al neolític Circulació i intercanvi de matèries, productes i idees a la Mediterrània occidental (VII-III mil.lenni aC)*. Gavà: Museu de Gavà; 2012. pp. 363–368. Available: <http://www.raco.cat/index.php/Rubricatum/article/view/269772>
 43. Salanova L. Techniques décoratives et périodisations céramiques en contexte non rubané. In: Burnez-Lanotte L, Ilett M, Allard P, editors. *Fin des traditions danubiennes dans le Néolithique du Bassin parisien et de la Belgique (5100–4700 av J-C): Autour des recherches de Claude Constantin*. Paris / Namur: Société préhistorique française / Presses universitaires de Namur; 2008. pp. 181–188.
 44. Eriksen BV. Fossil Mollusks and Exotic Raw Materials in Late Glacial and Early Find Contexts: A Complement to Lithic Studies. In: Fisher LE, Eriksen BV, editors. *Lithic raw material economy in late glacial and early postglacial western Europe*. Oxford: Bar International Series; 2002. pp. 27–52.
 45. Rigaud S, Gutiérrez-Zugasti I. Symbolism among the last hunter–fisher–gatherers in northern Iberia: Personal ornaments from El Mazo and El Toral III Mesolithic shell midden sites. *Quat Int*. 2016; <https://doi.org/10.1016/j.quaint.2015.10.029>
 46. Rigaud S, d'Errico F, Vanhaeren M. Los objetos de adorno personal asociados al esqueleto mesolítico Braña-2. In: Vidal Encinas JM, Encina Prada Marco M, editors. *Los hombres mesolíticos de la Cueva de la Braña-Arintero (Valdegueros, León)*. Leon: Museo de Leon; 2010. pp. 62–81.
 47. Vanhaeren M, d'Errico F. Childhood in the Epipaleolithic. What do personal ornaments associated to burials tell us? In: Larsson L, Kindgren H, Knutsson K, Leoffler D, Akerlund A, editors. *Mesolithic on the Move*. Oxbow Books. Oxford: Larsson L., Kindgren H., Knutsson K., Leoffler D. & Akerlund A.; 2003. pp. 494–505.
 48. White R. Intégrer la complexité sociale et opérationnelle: la construction matérielle de l'identité sociale à Sungir. *Préhistoire Os Recl Détudes Sur Ind Osseuse Préhistorique Offert À Henriette Camps-Fabrer*. 1999; 319–331.
 49. Boyd R, Richerson P. *Culture and the Evolutionary Process*. University of Chicago Press; 1985.
 50. Cavalli-Sforza LL, Feldman MW. *Cultural Transmission and Evolution: A Quantitative Approach*. Princeton: Princeton University Press; 1981.
 51. Shennan S. Descent with modification and the archaeological record. *Philos Trans R Soc B Biol Sci*. 2011; 366: 1070–1079. <https://doi.org/10.1098/rstb.2010.0380> PMID: 21357229
 52. Collard M, Shennan SJ. Patterns, processes and parsimony: studying cultural evolution with analytical techniques from evolutionary biology. In: Stark M, Bowser BJ, Horne L, editors. *Cultural transmission and material culture: breaking down boundaries*. Tucson: University of Arizona Press; 2008. pp. 17–33.
 53. Jordan P. Understanding the spread of innovations in prehistoric social networks: new insights into the origins and dispersal of early pottery in Northern Eurasia. 2010;
 54. Shennan SJ. *Genes, memes and human history. Darwinian archaeology and cultural evolution*. London, UK: Thames and Hudson; 2002.
 55. Tehrani J, Collard M. On the relationship between inter-individual cultural transmission and population-level cultural diversity: a case-study of weaving in Iranian tribal populations. *Evol Hum Behav*. 2009; 30: 286–300.
 56. García Martínez de Lagrán I, Garrido Pena R, Rojo Guerra MA, Alday Ruiz A, García Gazólez J, Sesma Sesma J. Cerámicas, estilo y neolitización: estudio comparativo de algunos ejemplos de la meseta norte y alto valle del Ebro. In: Bernabeu Aubán J, Rojo Guerra MA, editors. *Las primeras producciones cerámicas El VI milenio CAL AC en la península ibérica*. Valencia: Universitat de València—Departament de Prehistòria i Arqueologia; 2011. pp. 83–103. Available: <http://dialnet.unirioja.es/servlet/articulo?codigo=3892996>
 57. Manen C. Structure et identité des styles céramiques du Néolithique ancien entre Rhône et Èbre. *Gall Préhistoire*. 2002; 44: 121–165.

58. Rigaud S. La parure: traceur de la géographie culturelle et des dynamiques de peuplement au passage Mésolithique-Néolithique en Europe. *Sciences et environnements—Université de Bordeaux*. 2011.
59. Sackett J. Style and ethnicity in archaeology: the case for isochrestism. In: Hastorf CA, Conkey MW, editors. *The uses of style in archaeology*. Cambridge: Cambridge University Press; 1989. pp. 32–43. Available: http://ls-tlss.ucl.ac.uk/course-materials/ARCLG194_48814.pdf
60. Willoughby CC. An Analysis of the Decorations upon Pottery from the Mississippi Valley. *J Am Folk*. 1897; 10: 9–20. <https://doi.org/10.2307/533845>
61. Fewkes JW. The feather symbols in ancient Hopi designs. *Am Anthropol*. 1898; A11: 1–14. <https://doi.org/10.1525/aa.1898.11.1.02a00010>
62. Bernbeck R, Robb JE. Structure strikes back: Intuitive meanings of ceramics from Qale Rostam, Iran. *Material Symbols: Culture and Economy in Prehistory*. Carbondale: Center for Archaeological Investigations; 1999. pp. 90–111.
63. Campbell S. Understanding symbols: putting meaning to the painted pottery of Prehistoric Northern Mesopotamia. *Dev Pre-Estate Communities Anc East*. 2010; 147–155.
64. Longacre WA, Xia J, Yang T. I Want to Buy a Black Pot. *J Archaeol Method Theory*. 2000; 7: 273–293.
65. Tehrani JJ, Riede F. Towards an archaeology of pedagogy: learning, teaching and the generation of material culture traditions. *World Archaeol*. 2008; 40: 316–331. <https://doi.org/10.1080/00438240802261267>
66. Bowser BJ. From Pottery to Politics: An Ethnoarchaeological Study of Political Factionalism, Ethnicity, and Domestic Pottery Style in the Ecuadorian Amazon. *J Archaeol Method Theory*. 2000; 7: 219–248. <https://doi.org/10.1023/A:1026510620824>
67. Capelli C, Starnini E, Cabella R, Piazza M. The circulation of Early Neolithic pottery in the Mediterranean: A synthesis of new archaeometric data from the impressed Ware culture of Liguria (north-west Italy). *J Archaeol Rep*. 2017; 16: 532–541.
68. Hamon C, Allard P, Illet M, editors. *The Domestic Space in LBK Settlements*. Rahden/Westf.: Verlag Marie Leidorf GmbH; 2013.
69. Perrin T, Manen C, Sejalon P. *Le Néolithique ancien de la plaine de Nîmes (Gard, France)*. Toulouse: AEP; 2014.
70. Sciamia LD, Eicher JB. *Beads and Beadmakers: Gender, Material Culture and Meaning*. Oxford; 1998.
71. Carter B, Helmer M. Elite Dress and Regional Identity: Chimú-Inka Perforated Ornaments from Samanco, Nepeña Valley, Coastal Peru. *BEADS J Soc Bead Res*. 2015; 20: 46–74.
72. Perlès C, Vanhaeren M. Black Cyclope neritea Marine Shell Ornaments in the Upper Palaeolithic and Mesolithic of Franchthi Cave, Greece: Arguments for Intentional Heat Treatment. *J Field Archaeol*. 2010; 35: 298–309. <https://doi.org/10.1179/009346910X12707321358874>
73. d'Errico F, Vanhaeren M, Van Niekerk K, Henshilwood CS, Erasmus RM. Assessing the Accidental Versus Deliberate Colour Modification of Shell Beads: a Case Study on Perforated Nassarius kraussianus from Blombos Cave Middle Stone Age levels. *Archaeometry*. 2013; n/a-n/a. <https://doi.org/10.1111/arcm.12058>
74. Beck CH. *Classification and Nomenclature of Beads and Pendants*. Soc Antiqu Lond. 1926;
75. Whallon R, Brown J. *Essays on Archaeological Typology*. Evanston: Center for American Archaeology Press; 1982.
76. Adams WY, Adams EW. *Archaeological Typology and Practical Reality: A Dialectical Approach to Artefact Classification and Sorting*. Cambridge: Cambridge University Press; 1991.
77. Dupont C. Etude complémentaire: les invertébrés marins du «concheiro» de Toledo (Lourinhã, Portugal). In: Araújo AC, editor. *O concheiro de Toledo no contexto do Mesolítico inicial de litoral da Estremadura*. Lisboa: Instituto de Gestão do Património Arquitectónico e Arqueológico; 2011. pp. 185–227.
78. Riede F. Steps towards operationalizing an evolutionary archaeological definition of culture. In: Roberts B, Vander Linden M, editors. *Investigating Archaeological Cultures: Material Culture, Variability, and Transmission*. New York, US: Springer Verlag; 2011. pp. 245–270.
79. Lyman RL. Cultural Transmission in North American Anthropology and Archaeology, ca. 1895–1965. In: O'Brien MJ, editor. *Cultural Transmission and Archaeology: Issues and Case Studies*. Society for American Archaeology Press. Washington D.C.; 2008. pp. 10–20.
80. d'Errico F, Zilhao J, Julien M, Conard N. Neanderthal Acculturation in Western Europe?: A Critical Review of the evidence and its Interpretation. *Curr Anthropol*. 1998; 39: 1–44.
81. Zilhao J, d'Errico F, Bordes JG, Lenoble A, Texier JP, Rigaud JP. Analysis of Aurignacian interstratification at the Châtelperronian-type site and implications for the behavioral modernity of Neandertals. *PNAS*. 2006; 103: 12643–12648. <https://doi.org/10.1073/pnas.0605128103> PMID: 16894152

82. Bertolini M, Cristiani E, Modolo M, Visentini P, Romandini M. Late Epigravettian and Mesolithic foragers of the eastern Alpine region: Animal exploitation and ornamental strategies at Riparo Biarzo (Northern Italy). *Quat Int*. <https://doi.org/10.1016/j.quaint.2015.09.083>
83. Binder D, Maggi R. Le Néolithique ancien de l'arc liguro-provençal. *Bull Société Préhistorique Fr*. 2001; 411–422.
84. Bernabeu Auban J. La tradición cultural de las cerámicas impresas en la zona oriental de la península ibérica. Valencia: Servicio de Investigación prehistórica—Diputación provincial; 1989.
85. Jaccard P. Étude comparative de la distribution florale dans une portion des Alpes et des Jura. *Bull Soc Vaudoise Sci Nat*. 1901; 37: 547–579.
86. Ricotta C, Podani J, Pavoine S. A family of functional dissimilarity measures for presence and absence data. *Ecol Evol*. 2016; 6: 5383–5389. <https://doi.org/10.1002/ece3.2214> PMID: 27551390
87. Bray JR, Curtis JT. An ordination of the upland forest communities of Southern Wisconsin. *Ecol Monogr*. 1957; 27: 325–349.
88. Warton DI, Wright ST, Wang Y. Distance-based multivariate analyses confound location and dispersion effects. *Methods Ecol Evol*. 2012; 3: 89–101. <https://doi.org/10.1111/j.2041-210X.2011.00127.x>
89. Gray RD, Simon J, Greenhill Ross RM. The Pleasures and Perils of Darwinizing Culture (with phylogenies). 2007; 2: 369–375.
90. Lipo CP, O'Brien MJ, Collard M, Shennan S. *Mapping Our Ancestors: Phylogenetic Methods in Anthropology and Prehistory*. Aldine Transaction. New Brunswick and London; 2005.
91. Greenhill SJ, Currie TE, Gray RD. Does horizontal transmission invalidate cultural phylogenies? *Proc R Soc Lond B Biol Sci*. 2009; <https://doi.org/10.1098/rspb.2008.1944> PMID: 19324763
92. Currie TE, Greenhill SJ, Mace R. Is horizontal transmission really a problem for phylogenetic comparative methods? A simulation study using continuous cultural traits. *Philos Trans R Soc B Biol Sci*. 2010; 365: 3903–3912. <https://doi.org/10.1098/rstb.2010.0014> PMID: 21041214
93. Bryant D, Filimon F, Gray RD. Untangling our past: Languages, trees, splits and networks. In: Mace R, C H, Shennan S, editors. *The Evolution of Cultural Diversity: Phylogenetic Approaches*. London: UCL Press; 2005. pp. 67–84.
94. Huson DH, Bryant D. Application of Phylogenetic Networks in Evolutionary Studies. *Mol Biol Evol*. 2006; 23: 254–267. <https://doi.org/10.1093/molbev/msj030> PMID: 16221896
95. Huson DH. SplitsTree: analyzing and visualizing evolutionary data. *Bioinformatics*. 1998; 14: 68–73. PMID: 9520503
96. Gray RD, Bryant D, Greenhill SJ. On the shape and fabric of human history. *Philos Trans R Soc B Biol Sci*. 2010; 365: 3923–3933.
97. Wichmann S, Holman EW, Rama T, Walker RS. Correlates of Reticulation in Linguistic Phylogenies. *Lang Dyn Change*. 2011; 1: 205–240.
98. Terrell JE. Language and Material Culture on the Sepik Coast of Papua New Guinea: Using Social Network Analysis to Simulate, Graph, Identify, and Analyze Social and Cultural Boundaries Between Communities. *J Isl Coast Archaeol*. 2010; 5: 3–32. <https://doi.org/10.1080/15564890903142891>
99. Smouse P, Long J, Sokal R. Multiple regression and correlation extensions of the Mantel test of matrix correspondence. *Syst Zool*. 1986; 35: 627–632.
100. Oksanen J, Blanchet FG, Kindt R, Legendre P, Minchin PR, O'hara RB. *Vegan: Community ecology package R package version 2.0–7 (2013)* (url:<http://CRAN.R-project.org/package=vegan>). 2013.
101. Goslee SC, Urban DL. The ecodist Package for Dissimilarity-based Analysis of Ecological Data. *J Stat Softw Vol 1 Issue 7 2007*. 2007; <https://doi.org/10.18637/jss.v022.i07>
102. McRae BH, Nürnberger B. Isolation By Resistance. *Evolution*. 2006; 60: 1551–1561. <https://doi.org/10.1554/05-321.1> PMID: 17017056
103. Ruiz-González A, Gurrutxaga M, Cushman SA, Madeira MJ, Randi E, Gómez-Moliner BJ. Landscape Genetics for the Empirical Assessment of Resistance Surfaces: The European Pine Marten (*Martes martes*) as a Target-Species of a Regional Ecological Network. *PLoS ONE*. 2014; 9: e110552. <https://doi.org/10.1371/journal.pone.0110552> PMID: 25329047
104. Slatkin M. Isolation by Distance in Equilibrium and Non-Equilibrium Populations. *Evolution*. 1993; 47: 264–279. <https://doi.org/10.1111/j.1558-5646.1993.tb01215.x> PMID: 28568097
105. Bevan A, Conolly J. GIS, Archaeological Survey, and Landscape Archaeology on the Island of Kythera, Greece. *J Field Archaeol*. 2002; 29: 123–138. <https://doi.org/10.2307/3181488>
106. Menze BH, Ur JA. Mapping patterns of long-term settlement in Northern Mesopotamia at a large scale. *Proc Natl Acad Sci U S A*. 2012; 109: E778–E787. <https://doi.org/10.1073/pnas.1115472109> PMID: 22431607

107. Clarkson C, Bellas A. Mapping stone: using GIS spatial modelling to predict lithic source zones. *J Archaeol Sci.* 2014; 46: 324–333. <https://doi.org/10.1016/j.jas.2014.03.035>
108. Hammer O, Harper D, Ryan PD. Paleontological statistics software package for education and data analysis. *Palaeontol Electron.* 2001; 4: 1–9.
109. Bartier PM, Keller CP. Multivariate interpolation to incorporate thematic surface data using inverse distance weighting (IDW). *Comput Geosci.* 1996; 22: 795–799. [https://doi.org/10.1016/0098-3004\(96\)00021-0](https://doi.org/10.1016/0098-3004(96)00021-0)
110. Amante C, Eakins BW. ETOPO1 1 Arc-Minute Global Relief Model: Procedures, Data Sources and Analysis. NOAA Technical Memorandum NESDIS NGDC-24, 19 pp, March 2009. <http://www.ngdc.noaa.gov/mgg/global/global.html>. 2009.
111. Excoffier L, Smouse PE, Quattro JM. Analysis of molecular variance inferred from metric distances among DNA haplotypes: application to human mitochondrial DNA restriction data. *Genetics.* 1992; 131: 479–491. PMID: [1644282](https://pubmed.ncbi.nlm.nih.gov/1644282/)
112. Ross RM, Greenhill SJ, Atkinson QD. Population structure and cultural geography of a folktale in Europe. *Proc R Soc B Biol Sci.* 2013; 280. Available: <http://rspb.royalsocietypublishing.org/content/280/1756/20123065.abstract>
113. Rzeszutek T, Savage PE, Brown S. The structure of cross-cultural musical diversity. *Proc R Soc B Biol Sci.* 2012; 279: 1606–1612.
114. Paradis E. pegas: an R package for population genetics with an integrated–modular approach. *Bioinformatics.* 2010; 26: 419–420. <https://doi.org/10.1093/bioinformatics/btp696> PMID: [20080509](https://pubmed.ncbi.nlm.nih.gov/20080509/)
115. Eerkens JW, Lipo CP. Cultural transmission, copying errors, and the generation of variation in material culture and the archaeological record. *J Anthropol Archaeol.* 2005; 24: 316–334. <https://doi.org/10.1016/j.jaa.2005.08.001>
116. Lycett SJ. Dynamics of Cultural Transmission in Native Americans of the High Great Plains. Bicho N, editor. *PLoS ONE.* 2014; 9: e112244. <https://doi.org/10.1371/journal.pone.0112244> PMID: [25372277](https://pubmed.ncbi.nlm.nih.gov/25372277/)
117. Venables WN, Ripley BD. *Modern Applied Statistics with S.* Fourth Edition. New York: Springer; 2002.
118. Arnholt AT. BSDA: Basic Statistics and Data Analysis. <http://CRAN.R-project.org/package=BSDA>. R package version 1.01. 2012.
119. Sicoli MA, Holton G. Linguistic Phylogenies Support Back-Migration from Beringia to Asia. *PLoS ONE.* 2014; 9: e91722. <https://doi.org/10.1371/journal.pone.0091722> PMID: [24621925](https://pubmed.ncbi.nlm.nih.gov/24621925/)
120. Heggarty P, Maguire W, McMahon A. Splits or waves? Trees or webs? How divergence measures and network analysis can unravel language histories. *Philos Trans R Soc Lond B Biol Sci.* 2010; 365: 3829–3843. <https://doi.org/10.1098/rstb.2010.0099> PMID: [21041208](https://pubmed.ncbi.nlm.nih.gov/21041208/)
121. Novembre J, Johnson T, Bryc K, Kutalik Z, Boyko AR, Auton A, et al. Genes mirror geography within Europe. *Nature.* 2008; 456: 98. <https://doi.org/10.1038/nature07331> PMID: [18758442](https://pubmed.ncbi.nlm.nih.gov/18758442/)
122. Lao O, Lu TT, Nothnagel M, Junge O, Freitag-Wolf S, Caliebe A, et al. Correlation between Genetic and Geographic Structure in Europe. *Curr Biol.* 2008; 18: 1241–1248. <https://doi.org/10.1016/j.cub.2008.07.049> PMID: [18691889](https://pubmed.ncbi.nlm.nih.gov/18691889/)
123. Bryant D, Moulton V, Spillner A. Consistency of the Neighbor-Net Algorithm. *Algorithms Mol Biol.* 2007; 2: 8. <https://doi.org/10.1186/1748-7188-2-8> PMID: [17597551](https://pubmed.ncbi.nlm.nih.gov/17597551/)
124. Ross RM, Atkinson QD. Folktale transmission in the Arctic provides evidence for high bandwidth social learning among hunter–gatherer groups. *Evol Hum Behav.* 2016; 37: 47–53. <https://doi.org/10.1016/j.evolhumbehav.2015.08.001>
125. Buckley CD. Investigating Cultural Evolution Using Phylogenetic Analysis: The Origins and Descent of the Southeast Asian Tradition of Warp Ikat Weaving. *PLoS ONE.* 2012; 7: e52064. <https://doi.org/10.1371/journal.pone.0052064> PMID: [23272211](https://pubmed.ncbi.nlm.nih.gov/23272211/)
126. Lee S, Hasegawa T. Oceanic barriers promote language diversification in the Japanese Islands. *J Evol Biol.* 2014; 27: 1905–1912. <https://doi.org/10.1111/jeb.12442> PMID: [24953224](https://pubmed.ncbi.nlm.nih.gov/24953224/)
127. Gosselain OP. Materializing Identities: An African Perspective. *J Archaeol Method Theory.* 2000; 7: 187–217.
128. Hegmon M. Advances in Ceramic Ethnoarchaeology. *J Archaeol Method Theory.* 2000; 7: 129–137. <https://doi.org/10.1023/A:1026502419007>
129. Álvarez Fernández E. The use of *Columbella rustica* (Clase: Gastropoda) in the Iberian Peninsula and Europe during the Mesolithic and Early Neolithic. In: Hernández Pérez M, Soler García JA, López Padilla JA, editors. *V Congreso del Neolítico Peninsular* (Alicante, 27–30 noviembre 2006). Alicante: Museo Arqueológico de Alicante, Diputación Provincial de Alicante; 2008. pp. 103–111.

130. MacNeish RS. Iroquois Pottery Types: A Technique for the Study of Iroquois Prehistory, Issue 31. Department of Resources and Development, National Parks Branch. Ottawa: National Museum of Canada; 1952.
131. Stiner MC. "Standardisation" in Upper Paleolithic ornaments at the coastal sites of Riparo Mochi and Uçagizli. In: ZILHAO J, D'ERRICO F, editors. *The Chronology of the Aurignacian and of the Transitional Technocomplexes Dating, Stratigraphies, Cultural Implications*. Lisbon: Instituto Portugues de Arqueologia; 2003. pp. 49–59.
132. Stiner MC. Finding a Common Bandwidth: Causes of Convergence and Diversity in Paleolithic Beads. *Biol Theory*. 2014; 9: 51–64. <https://doi.org/10.1007/s13752-013-0157-4>
133. Vanhaeren M. *Les fonctions de la parure au Paléolithique supérieur: de l'individu à l'unité culturelle*. Editions Universitaires Européennes, Sarrebruck. 2010;
134. Verswijver G. Essai sur l'usage de la parure des Indiens Kayapo du Brésil central. *Bull Annu Mus Ethnogr Ville Genève Genève*. 1982; 25–26: 23–62.
135. Carey M. *Beads and Beadwork of East and South Africa*. Aylesbury: Shire; 1986.
136. Schoeman S. Eloquent beads, the semantics of a Zulu art form. *Afr Insight*. 1983; 13: 5–25.
137. Barth F. *Ethnic groups and boundaries: The social organization of culture difference*. Waveland Press; 1998.
138. Harrison S. The Politics Of Resemblance: Ethnicity, Trademarks, Head-Hunting. *J R Anthropol Inst*. 2002; 8: 211–232. <https://doi.org/10.1111/1467-9655.00001>
139. García-Martínez de Lagrán Í, Fernández-Domínguez E, Rojo-Guerra MA. Solutions or illusions? An analysis of the available palaeogenetic evidence from the origins of the Neolithic in the Iberian Peninsula. *Quat Int*. <https://doi.org/10.1016/j.quaint.2017.07.012>
140. Zilhao J. Radiocarbon evidence for maritime pioneer colonization at the origins of farming in west Mediterranean Europe. *98(24):14,180–14,185. Proc Natl Acad Sci*. 2001;98: 180–14, 185.
141. García-Martínez de Lagrán Í. Recent Data and Approaches on the Neolithization of the Iberian Peninsula. *Eur J Archaeol*. 2015; 18: 429–453. <https://doi.org/10.1179/1461957114Y.0000000084>