Cultural wave front expansion explains multiple stages of diversity during the Neolithic Transition in Europe

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Abstract

The Axelrod model of cultural dissemination is a convenient analogue to the description of archaeological cultures based on a series of material features, such as styles of pottery, agriculture, domestication, etc. Allowing a population to spread into uninhabited, or sparsely inhabited, territory, while undergoing cultural interaction, generates a ‘wave front’ containing larger homogeneous cultures, with a backwater of diversity. A very similar process is observed in the neolithic transition - the arrival of the first farming technology at the end of the Mesolithic - in south-eastern Europe (c. 8000-6000 cBC), where the first observable neolithic cultures are large and homogeneous, and these are succeeded by greater diversity. The model presented here demonstrates how the dynamics of a spreading wave can explain the observed progression from large, spreading cultures to smaller, more diverse cultures.

Introduction

Archaeological cultures are commonly identified based on a set of material features common to sites belonging to that culture. Such features can include the types or styles of pottery, stone tools, agriculture, or animal husbandry used, among others (Clarke, 1968). For sites related to the neolithic transition in South-Eastern Europe, analysis of this material culture shows a progression from large, homogeneous and distinct cultures present initially (Figure 1a), to smaller, more diverse and inter-related cultures 3-500 years later (Figure 1b).

Data such as that for the latter sites can be difficult to interpret, as it does not allow cultures to be easily distinguished based on any one, or even several, material features. There is both a greater overlap between the features of spatially distant sites, and a greater variety in the features of nearby sites, when compared with data from the earlier sites.

As demonstrated by Bocquet-Appel et al. (2009), the neolithic transition is accompanied by a ‘wave front’ of increased population, that spreads gradually into Europe. Modelling this spread of a population into a previously unoccupied, or sparsely occupied, region suggests that the apparent progression from homogeneous to diverse culture is a natural consequence of the spreading process, rather than being an artefact of noisier data.

Theory

Assuming a culturally heterogeneous initial population that is bordered, in some or all directions, by unoccupied area, an expanding front will form along any boundary which is not enclosed. Whereas cultures in a saturated area may spread by interaction with neighbouring cultures, those on the front have access to unoccupied neighbouring sites, and are able to replicate themselves into that area without modification, allowing them to expand much more quickly than if they were enclosed.

Over a longer time period, the greater diversity behind the front also spreads, through the action of interaction rather than replication, and may erode the original front cultures. These diverse cultures both compete and mix with each other, forming an intermixed assortment of cultures: some growing larger; some being eliminated; and others dividing into partly related subcultures.

If the rate of spreading/replication is sufficiently high compared to the rate of cultural interaction, then large areas of homogeneous culture can form in the spreading front, faster than they are eroded by cultural interaction with dissimilar cultures behind them.

Unlike replication, this cultural interaction is not directed by the availability of space, and spreads much more slowly into the area occupied by the front. When this diversity does reach an area previously outside the initial area, possibly long after the front population, it will consist of several small-medium sized cultures, larger the further they’ve had to travel from the initial area.

The arrival of this chaos is visible in the CA results (Figure 1b) as both a greater diversity within closely spaced sites, and less distinction between distantly related sites - which may previously have been located in different culturally homogeneous streams.

Model

The cultural dissemination model of Axelrod (1997) provides a good analogue to the description of archaeological cultures based on assemblages of material features. This is adapted to the scenario of a spreading population by includ-
Figure 1: Correspondence analysis of animal species’ distribution in zooarchaeological assemblages for (a) early (c. 6000-5400 BC) and (b) late (c. 5400-4500 BC) Neolithic. Points are colored by geographic region (c), not all sites are present in both plots (a) and (b).

(a) Large homogenous culture on wave front, after 90,000 steps

(b) Diverse cultures erode territory of original front, after 240,000 steps

Figure 2: One realisation of the modified Axelrod model showing the spread of two large homogeneous wave front cultures (a), followed by their erosion by more diverse cultures (b). Line thickness indicates level of cultural dissimilarity, unshaded areas are unoccupied.

importing initially unpopulated loci, into which a culture can clone itself without modification, in a demographic step which occurs once for every \( N \) typical interaction steps.

A cultural interaction consists of comparing two randomly selected neighbouring sites, and with probability equal to their cultural similarity - the proportion of features for which they are equal - setting one of the dissimilar features in one site to the value in the other. A demographic step consists of randomly selecting two neighbouring sites, and if one is occupied and the other is not, cloning the culture of the occupied site into the unoccupied site. This simple addition results in the formation of the homogeneous front described above, along with a more diverse ‘backwater’, which gradually encroaches on the area first occupied by the front. Simultaneously, the cultures in this backwater are mixed, resulting in some cultures growing geographically to the exclusion of others.

Importantly, this model simulates the behaviour of culture, not people. Sites are either occupied or not, and need to be occupied to have culture. The spread of one culture into another does not imply any change in the population there, only a change in their culture.

The model is also neutral - no trait or feature is selected over any other - all interactions happen at random, as in the original Axelrod model. The only fitness differential arises from the ability of sites with unoccupied neighbours to clone themselves.

Conclusion

The ability for cultures on a spreading front to replicate themselves without mixing or modification, followed by the erosion of this front by more diverse culture over time, may offer the first process based explanation of the observed tendency from initial homogeneity to later diversity, common to many spreading phenomenon in archaeology.

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References

