

A computational Cultural Transmission model of Bronze Age burial rites in Central, Northern and North-western Europe

Observations on spatial and cultural distance

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Evolution of
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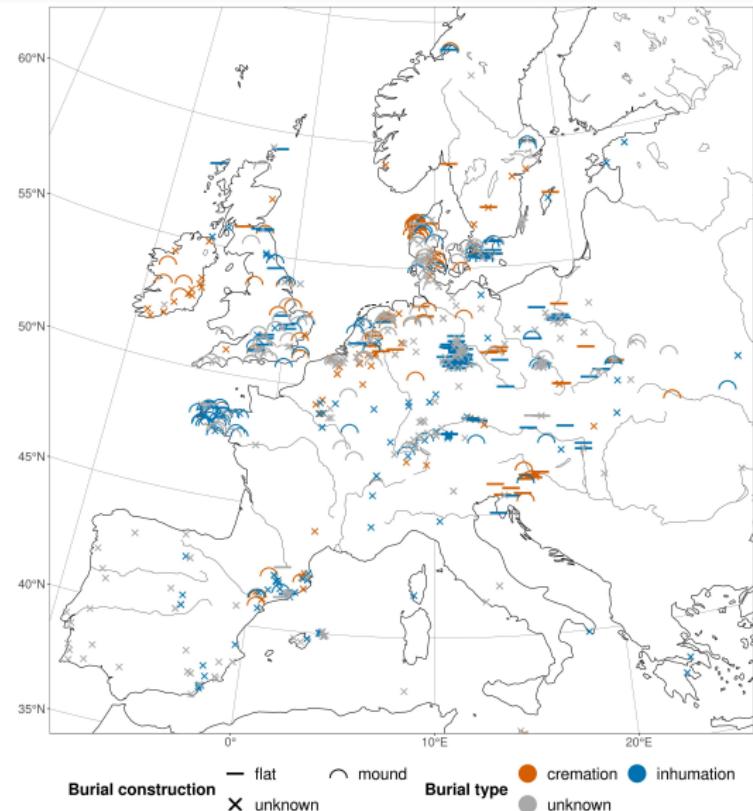
- Introduction to the data
- Cultural Distance
- Cultural and Spatial Distance
- Simulation

Introduction

Data

Radon-B:
Database of ^{14}C dates for the
European Bronze Age

^{14}C dating is an important absolute dating method: One date equals a fuzzy point in space and time with context information



Context for dates from graves:
burial type & burial construction

Heterogeneous information density in space and time

Figure 1: Radon-B ^{14}C dates of graves 2200-800 calBC (Albers Equal Area Conic).

Research Area and Regions

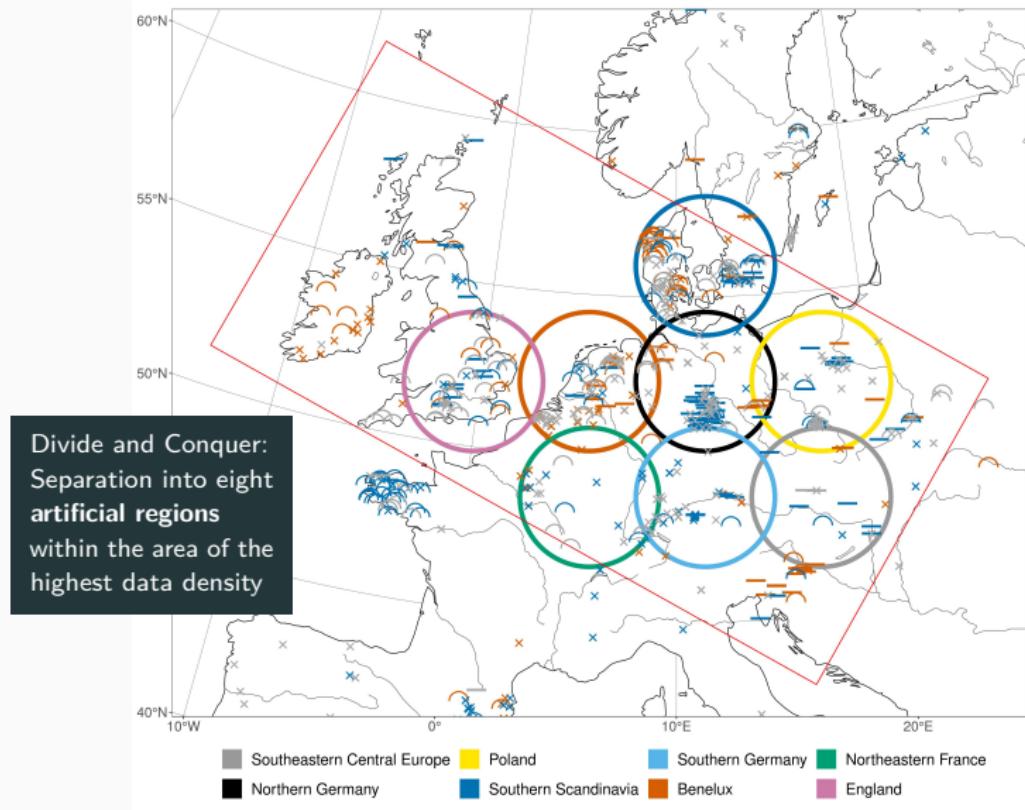


Figure 2: Artificial Regions: 400km distance, 240km radius, ≥ 70 dates.

Development – Absolute Numbers

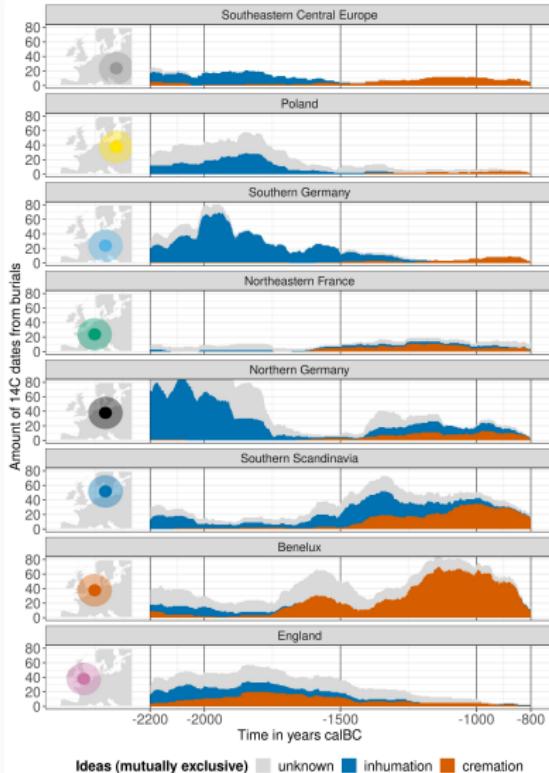


Figure 3: burial type development: Sum of ^{14}C dates whose 2σ range cover the respective year.

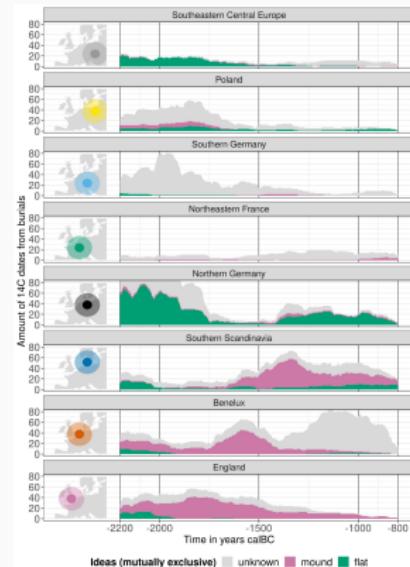


Figure 4: burial construction

Data structure transformation:
Individual ^{14}C dates to region wise
time series of burial rite presence

Development – Proportions

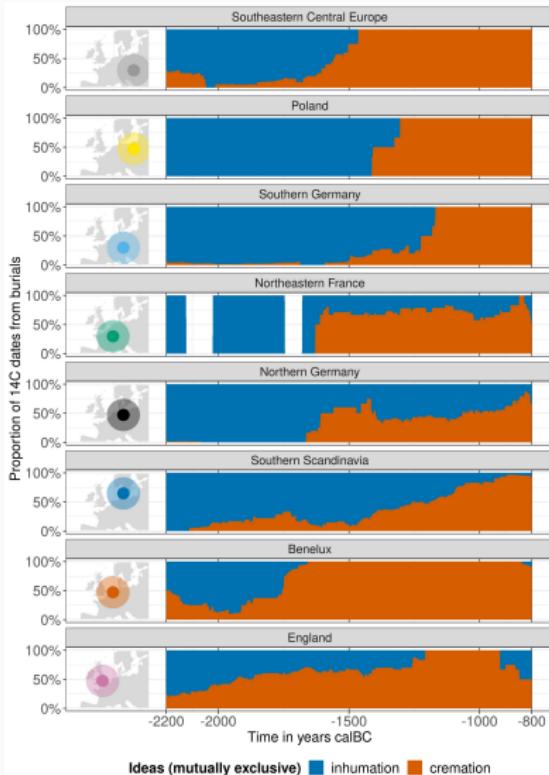


Figure 5: burial type development: Year wise proportions of dates. *unknown* is filtered out.

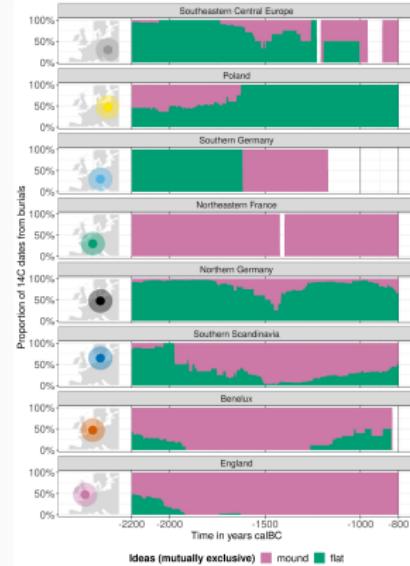


Figure 6: burial construction

Data structure transformation:
Time series of absolute appearances
to time series of burial rite
proportions – burial rite proxy

Cultural Distance

Squared Euclidian Distance (SED)

Question: How do the developments in these regions for **burial type** and **burial construction** relate to each other? Which regions behave alike?

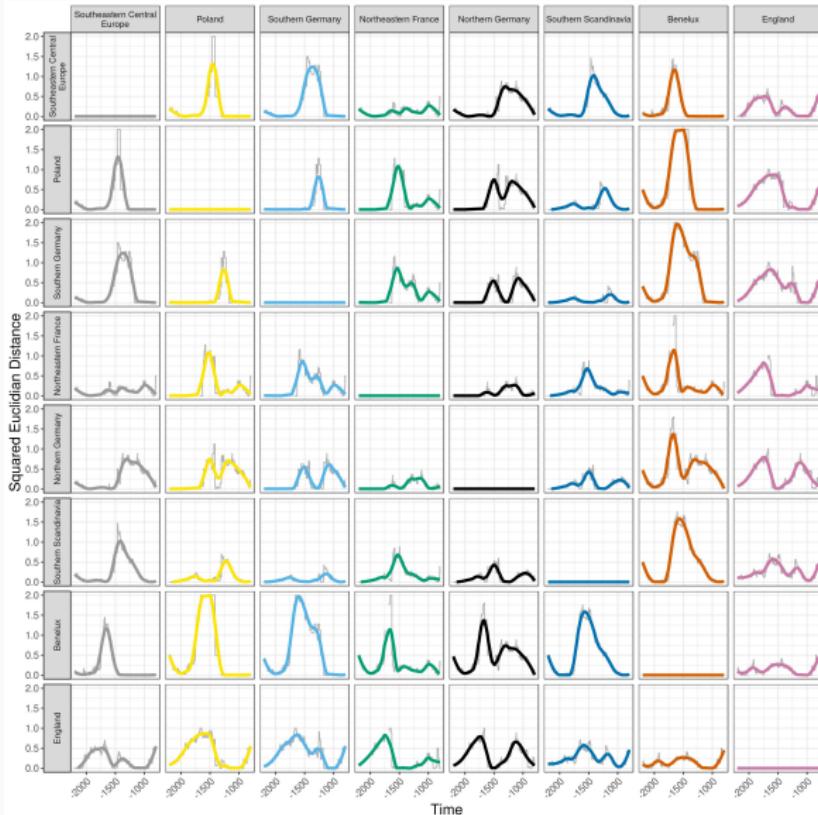
The **Squared Euclidian Distance** is a simple measure of between-group similarity that can be applied to the **burial rite proxy** data.

$$d_{ij}^2 = \sum_{k=1}^n (p_{ik} - p_{jk})^2$$

- d_{ij}^2 : Squared Euclidean Distance between two groups i and j
- k : Variant counter
- n : Total amount of variants in a population
- p_{ik} : Relative frequency of the k 'th variant in population i
- p_{jk} : Relative frequency of the k 'th variant in population j

Region-Region Distance Matrix

The SED can be calculated for every year of every one of the $8 * 8 = 64$ region relationships



Low distance at the start and end due to the universal shift from inhumation to cremation with rise of the Urnfield culture

The different adoption rates are visible as peaks of cultural distance

Figure 7: burial type: SED for each region relationship. Approximated with LOESS.

Parallel Developments?

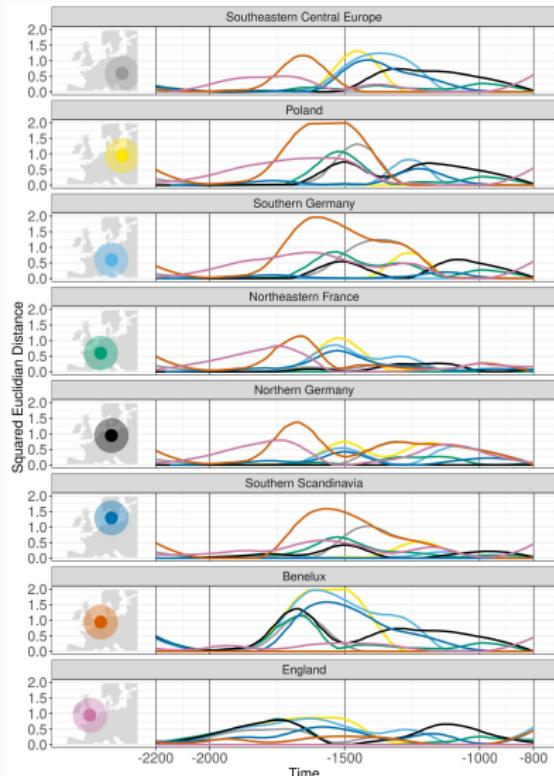


Figure 8: burial type Development of SED to all the others for each region.

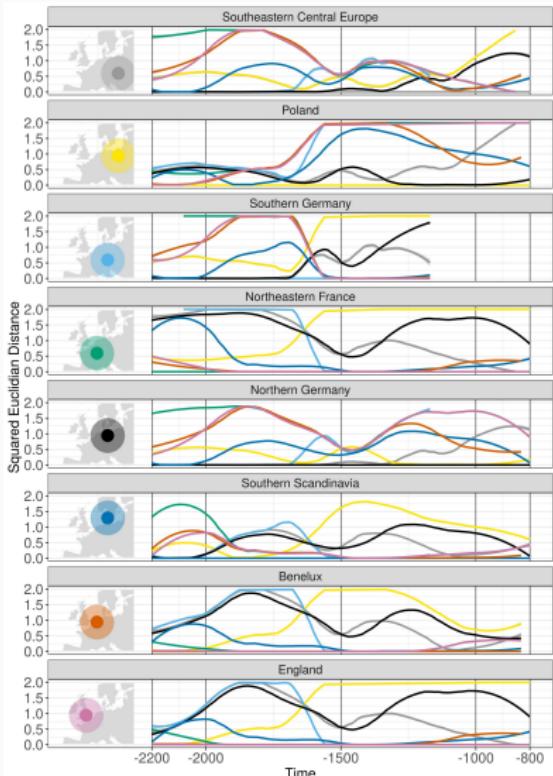


Figure 9: burial construction

Correlation of Burial Type and Burial Construction Distance

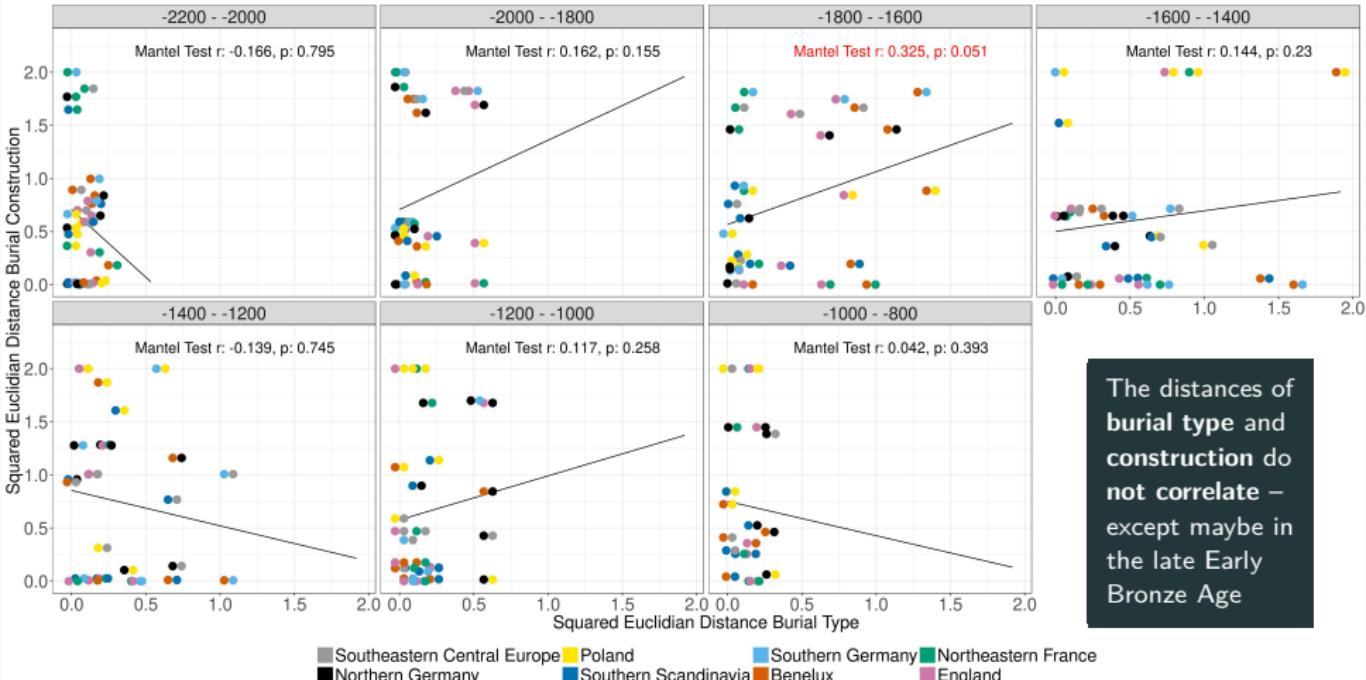


Figure 10: Correlation of burial type and burial construction mean SED in time slices of 200 years.
Each double point represents one region-region relationship.

The distances of burial type and construction do not correlate – except maybe in the late Early Bronze Age

Cultural and Spatial Distance

Spatial Distance Classes

The definition of artificial regions as units of analysis makes distance measures difficult. **Ordinally scaled distance classes** are the only valid option here.

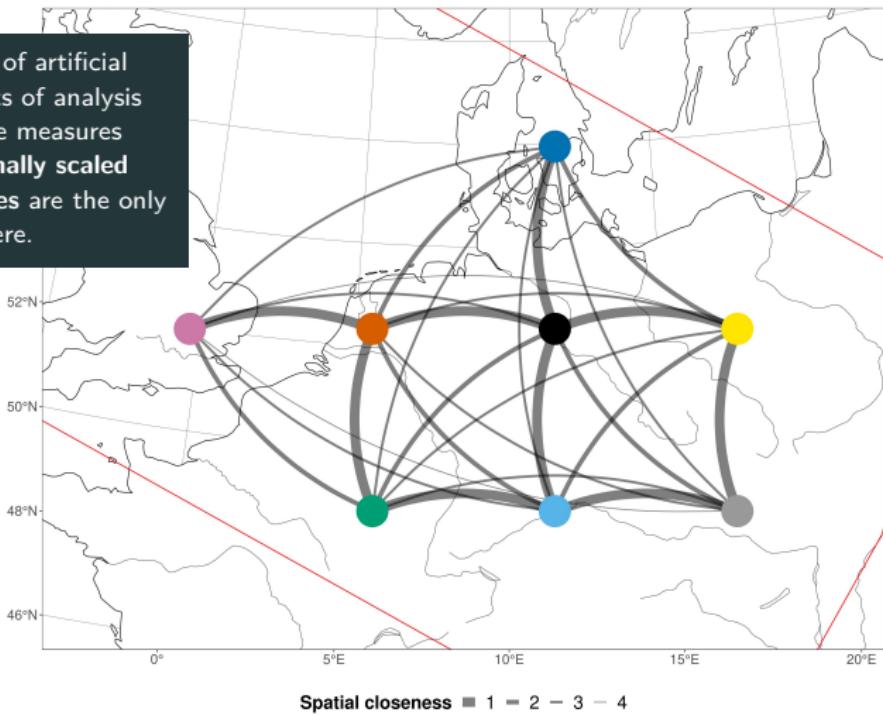


Figure 11: Spatial distance network and definition of distance classes

Correlation of Burial Type and Spatial Distance

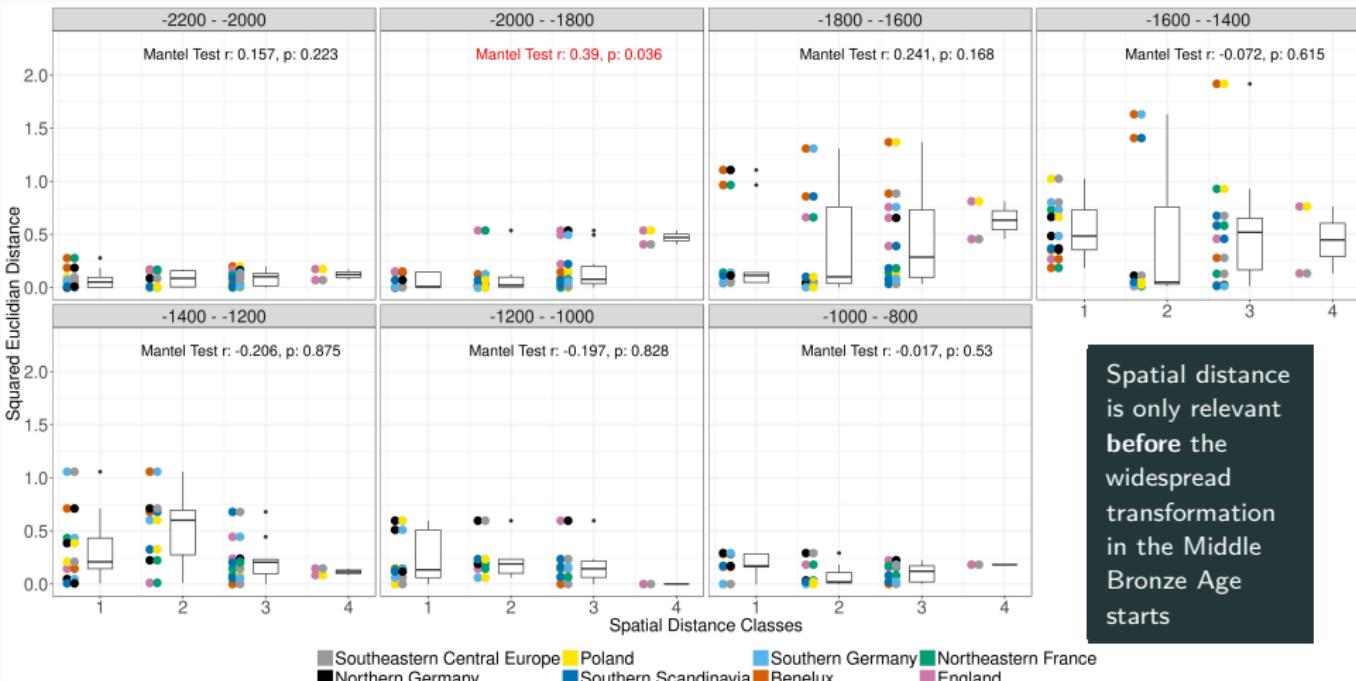
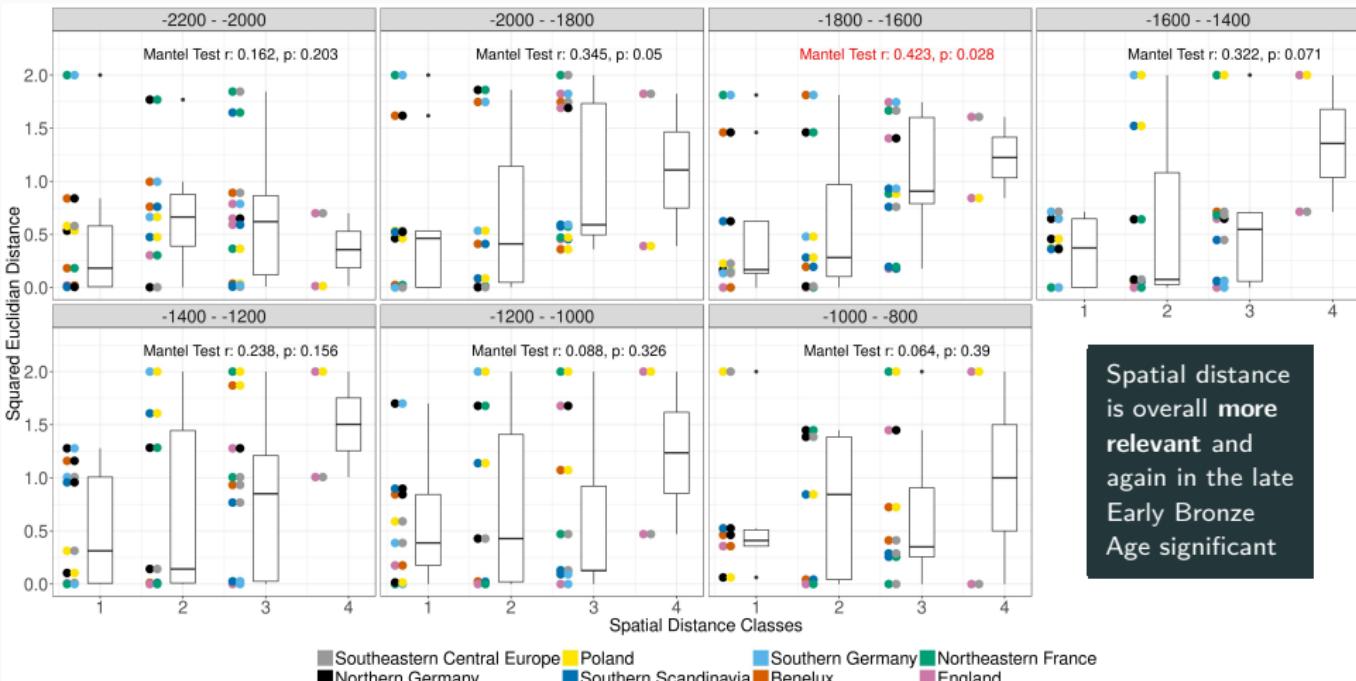


Figure 12: burial type: Correlation of mean SED and spatial distance in timeslices of 200 years.

Correlation of burial construction and spatial distance



Spatial distance
is overall **more relevant** and
again in the late
Early Bronze
Age significant

Figure 13: burial construction: Correlation of mean SED and spatial distance in timeslices of 200 years.

Simulation

Preliminary Considerations

Funeral rituals are **behaviour/ideas/cultural traits** and spread in space and time. They exist in **social space** and their spread depends on social relationships.

Simulation concept:

- Ideas are **entities** with simple behaviour: **greedy expansion**
 - Ideas live in a configurable, diachronic **population network**
-

Funeral rituals are a special category of ideas: They have a relatively low interaction with the human-environment system and can be treated as **selectively neutral**. [Dunnell 1978]

The main mechanisms of diffusion of neutral variants are **innovation, drift** and **flow**. [Neiman 1995]

- **Drift:** Individual traits will dominate due to stochastic processes
- **Flow:** Information transfer causes synchronization across group boundaries

Population Graph Creation

R Package to create undirected population networks with configurable **population size development**, **number of groups**, **degree of intra- and intergroup transmission**, etc.

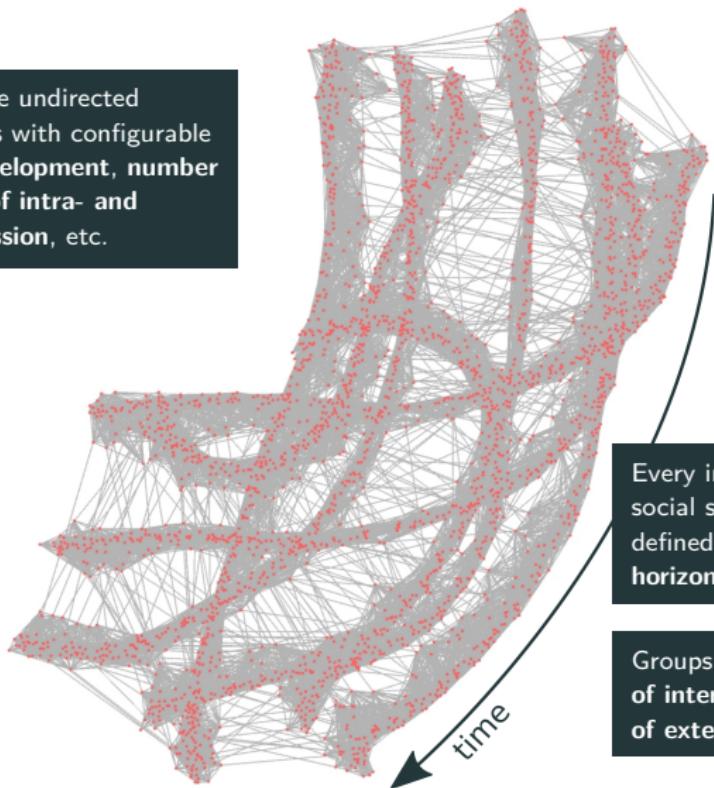


Figure 14: Example Population Graph. Arranged with the Fruchterman & Reingold algorithm.

Idea Expansion Simulation

```
...
// make random decision to convert or ignore a node based on the edge weight
std::vector<std::pair<int, bool>> success_per_neighbor(neighbors.size());
for (auto& i : all_neighbors_information) {
    // make decision
    // if the node is already occupied, it's more difficult
    // if more than one contact, then there's a convincing bonus
    std::pair<int, bool> success;
    if (std::get<3>(i)) {
        success = std::make_pair(
            std::get<0>(i),
            std::get<1>(i) * log2(std::get<2>(i) + 1) >= randunifrange(75, 100)
        );
    } else {
        success = std::make_pair(
            std::get<0>(i),
            std::get<1>(i) * log2(std::get<2>(i) + 1) >= randunifrange(0, 100)
        );
    }
    success_per_neighbor.push_back(success);
}
...

```

C++ CLI program to simulate idea expansion within the population network

Simulation Application: Correlation of Spatial and Cultural Distance

Can
correlation of
spatial and
cultural
distance be
ruled out?

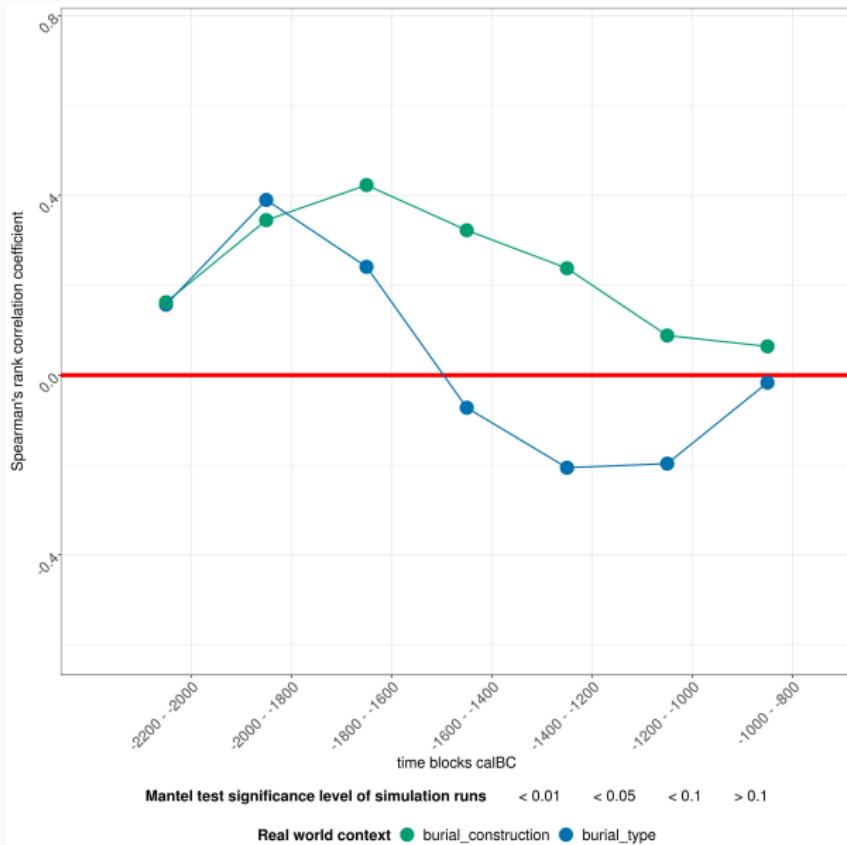


Figure 15: Correlation of cultural and spatial distance over time for **real world observations**.

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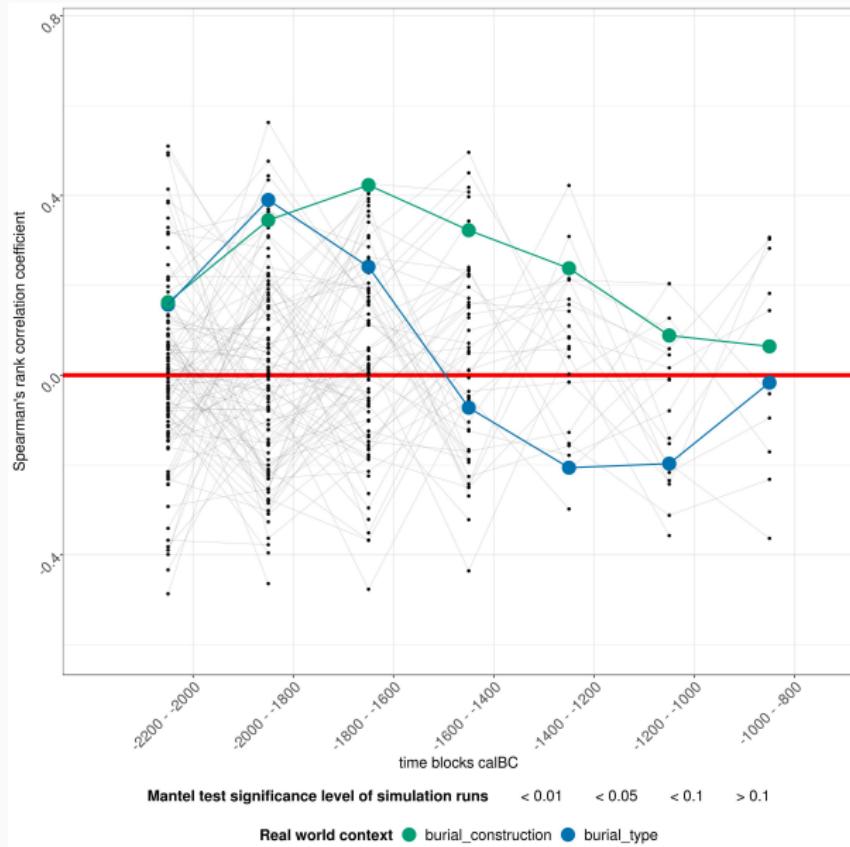


Figure 16: + Correlation development for 100 simulation runs with equal intergroup distance.

Simulation Application: Correlation of Spatial and Cultural Distance

Can correlation of spatial and cultural distance be ruled out?

Equal intergroup distance:
Unlikely development in the Early Bronze Age

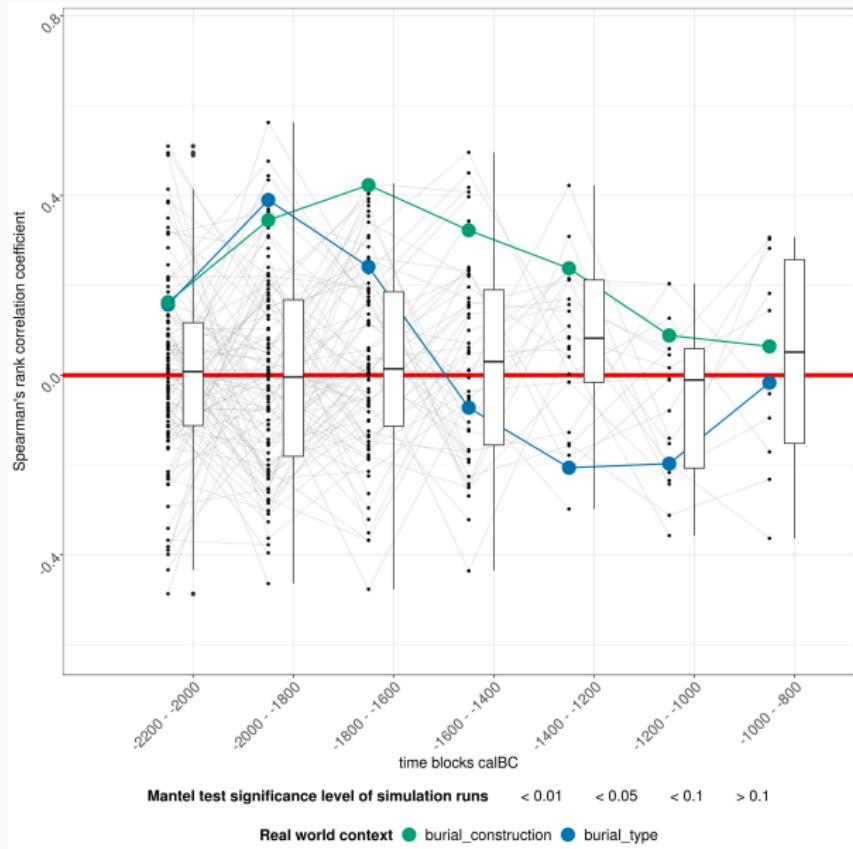


Figure 17: + Diagnostic boxplots for simulation runs.

Simulation Application: Correlation of Spatial and Cultural Distance

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Equal
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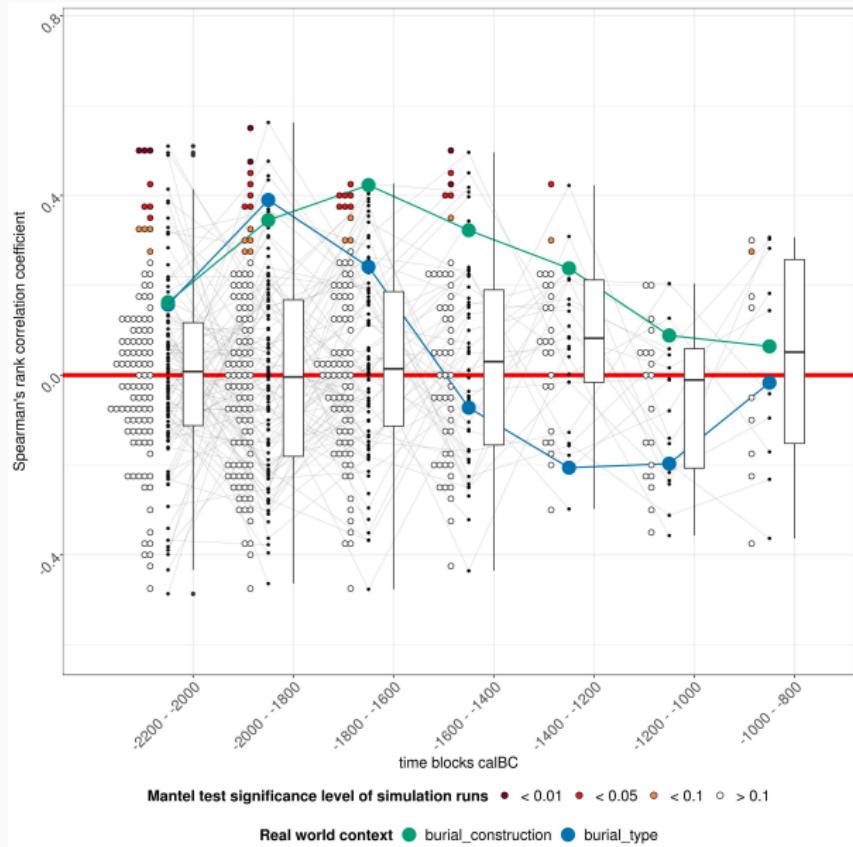


Figure 18: + Diagnostic dotplots indicating mantel test results.

Simulation Application: Correlation of Spatial and Cultural Distance

Can correlation of spatial and cultural distance be ruled out?

Equal intergroup distance: Unlikely development in the Early Bronze Age

Spatial intergroup distance: Unlikely development in the Late Bronze Age

burial type behaves highly atypical if we assume spatial correlation

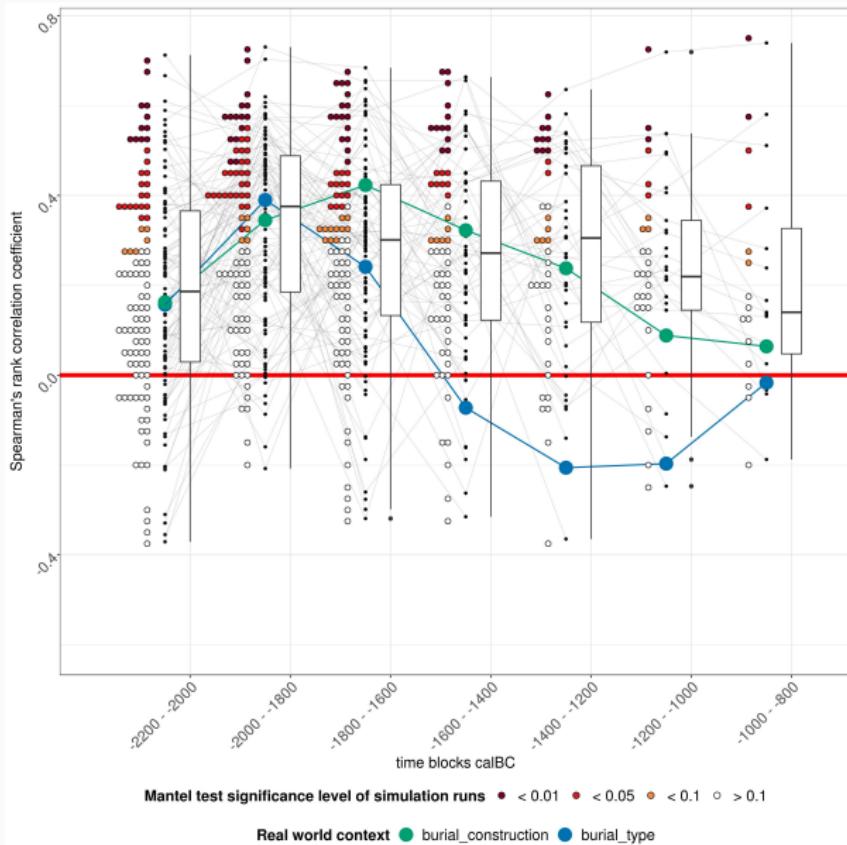


Figure 19: Same plot, but simulations now with spatial intergroup distance.

Conclusion

Observations and Hypotheses

- The diffusion of the **cremation funeral tradition** and **traditions of flat vs. mound graves** are **independent**.
 - Both processes are **mostly independent** of **spatial distance**: Not a simple diffusion process!
 - **Other interaction networks** could yield better predictions: Elite Networks, Religious superstructures, ...
-
- **Sociocultural complexity** in the Bronze Age is generally **increasing**. Still the **homogeneity & heterogeneity** of certain cultural traits **vary greatly**.

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