

# Quantitative analysis of cultural trait development

Evaluating Cultural Transmission in Bronze Age burial rites of Central, Northern and North-western Europe using radiocarbon data

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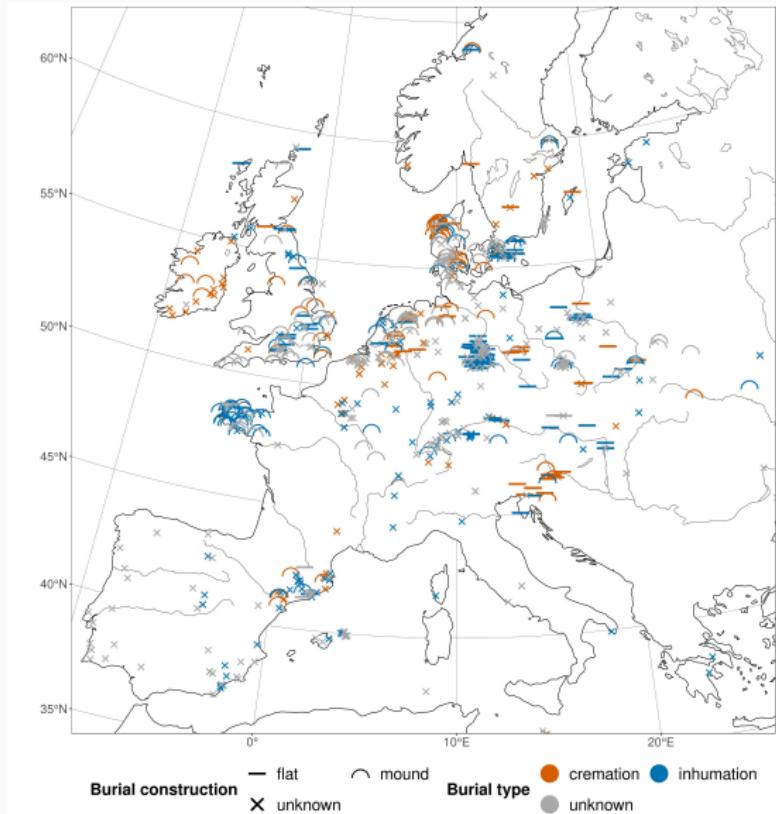
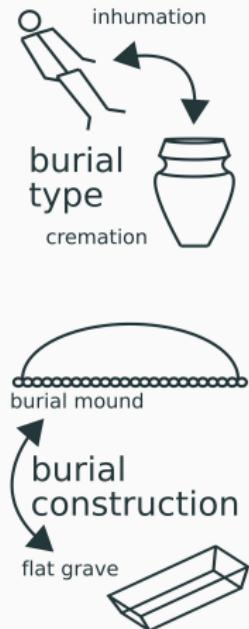
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- Introduction to the data
- Cultural Distance
- Cultural and Spatial Distance
- Simulating Cultural Transmission

## **Introduction**

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# Radiocarbon dates on graves

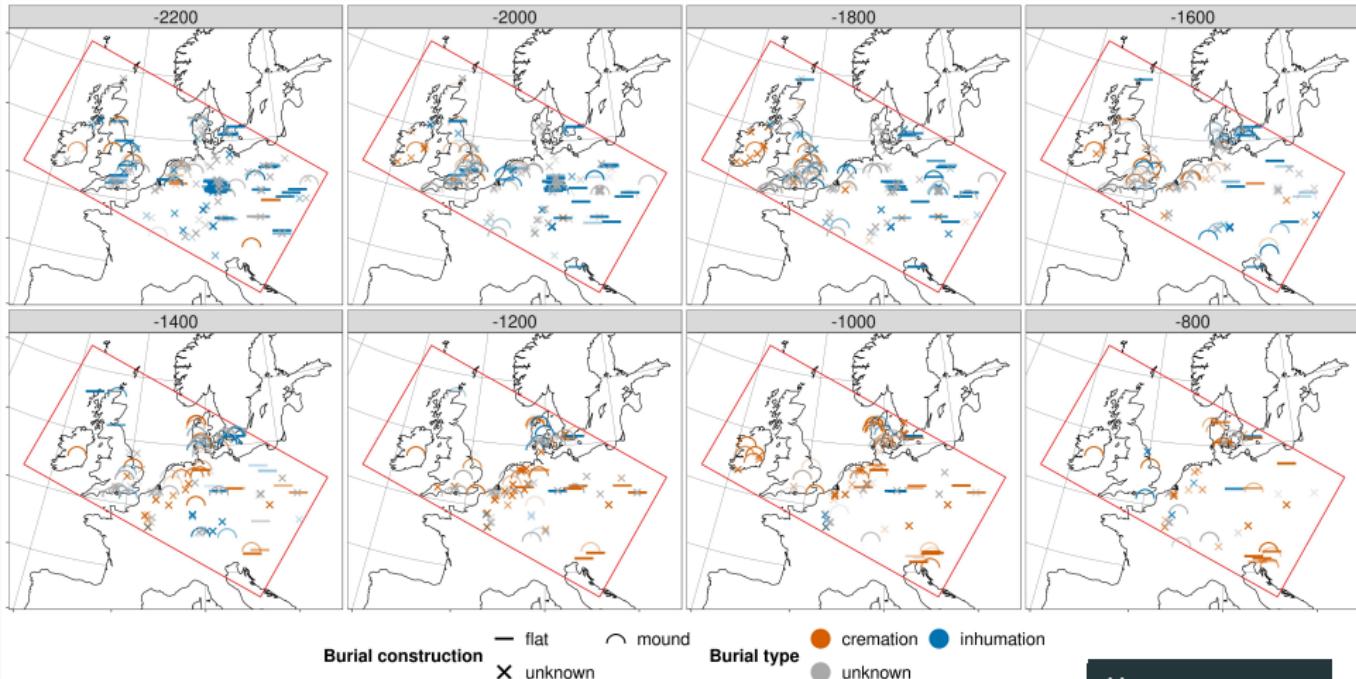


**Radon-B:**  
Database of  $^{14}\text{C}$  dates for the  
European Bronze Age

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

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

# Dates on Graves through Time



**Figure 2:** Plot matrix of radiocarbon dates on graves through time.  
200 years time slices.

Heterogeneous  
information  
density in space  
and time

# Artificial Macro-Regions

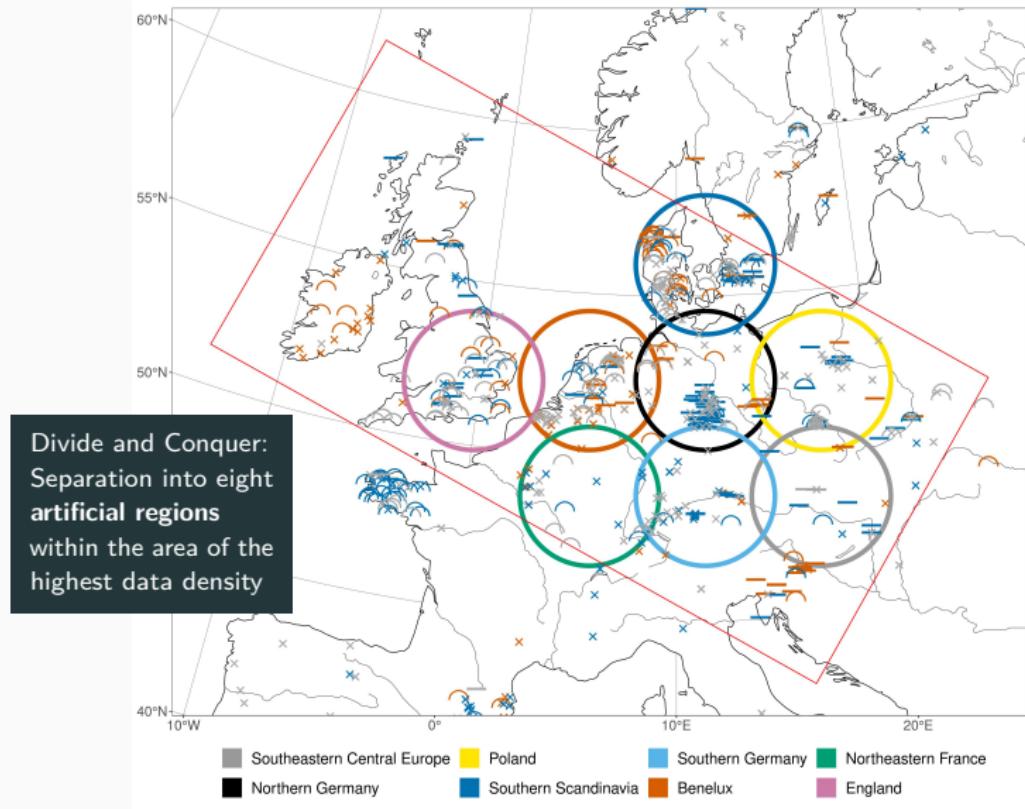
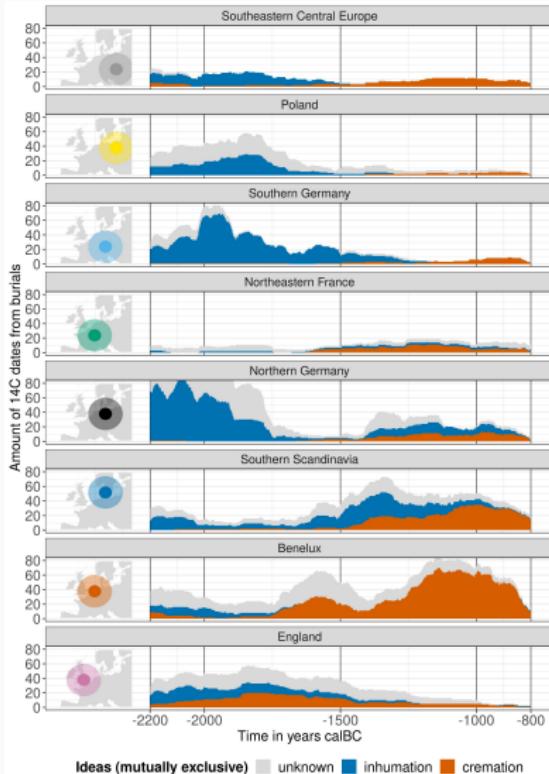
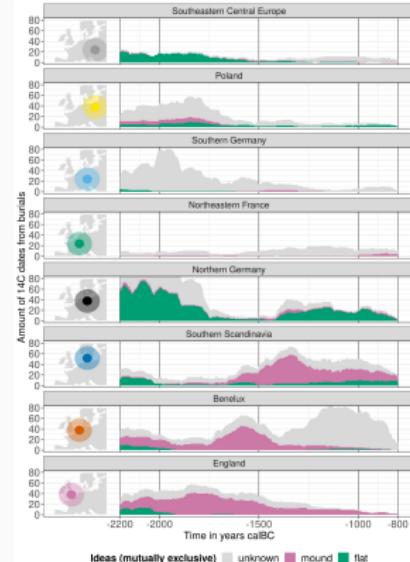


Figure 3: Artificial Regions: 400km distance, 240km radius,  $\geq 70$  dates.

# Development – Absolute Numbers



**Figure 4: burial type development:** Sum of  $^{14}\text{C}$  dates whose  $2\sigma$  range cover the respective year.



**Figure 5: burial construction**

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

# Development – Proportions

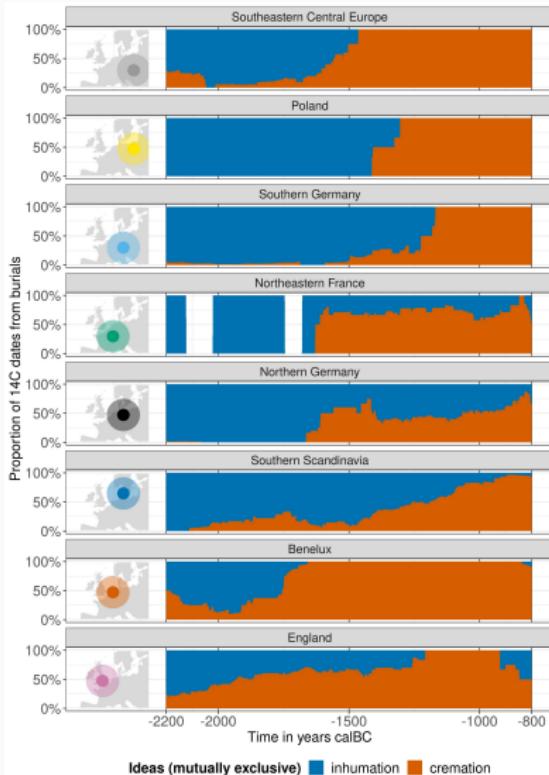


Figure 6: burial type development: Year wise proportions of dates. *unknown* is filtered out.

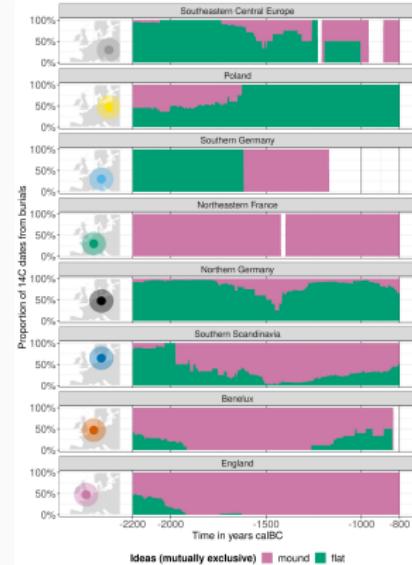


Figure 7: burial construction

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

## Cultural Distance

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## Measuring cultural distance

How do the developments in these regions for **burial type** and **burial construction** relate to each other? Which regions behave alike? Can we measure spatial **interaction intensity**?

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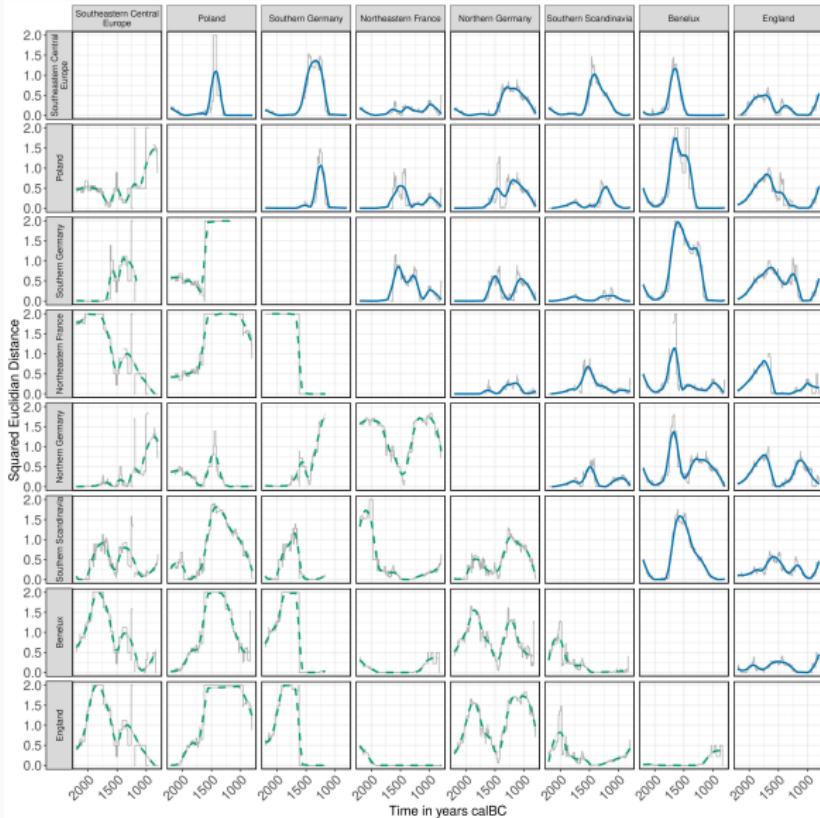
The **Squared Euclidian Distance** is a simple **measure of between-group similarity** that can be applied to the **burial rite proxy** data.

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

- $d_{ij}^2$ : 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



burial  
construction:  
Heterogeneous  
distance  
development

**burial type:**  
Low distance at the start and end due to the universal shift from inhumation to cremation (Urnfield culture)

The different adoption rates are visible as peaks of cultural distance

Figure 8: SED timeseries for each region relationship. Approximated with LOESS. **burial type** on top, **burial construction** in the bottom left corner.

# Mean Region-Region Distance Matrix

Central  
European  
Cluster?

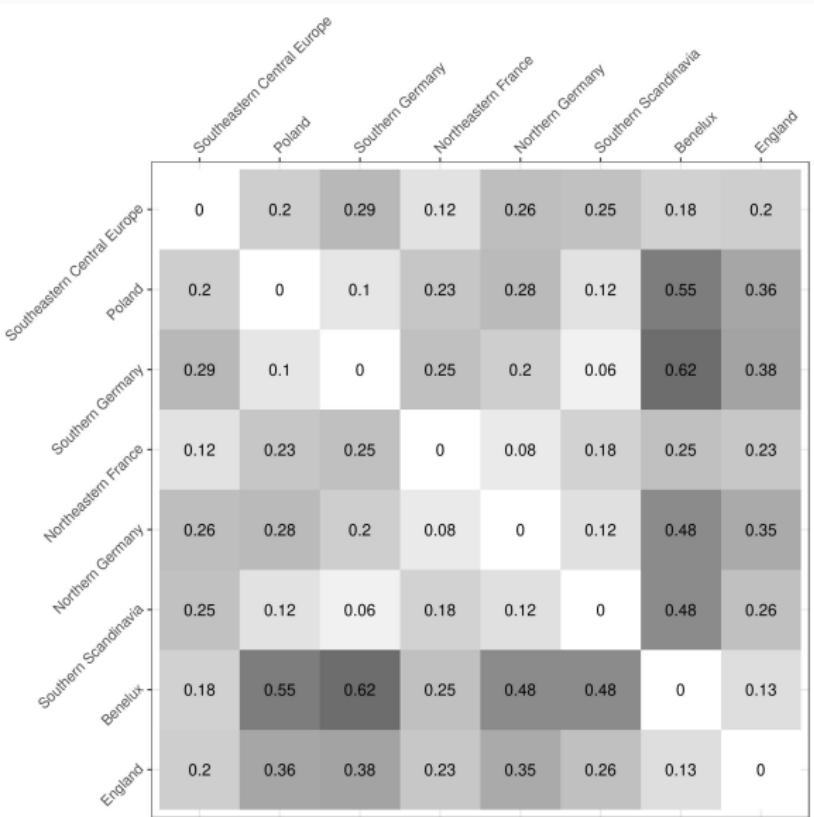


Figure 9: burial type: Mean SED for each region relationship. The lower, the closer.

# Mean Region Distance Matrix

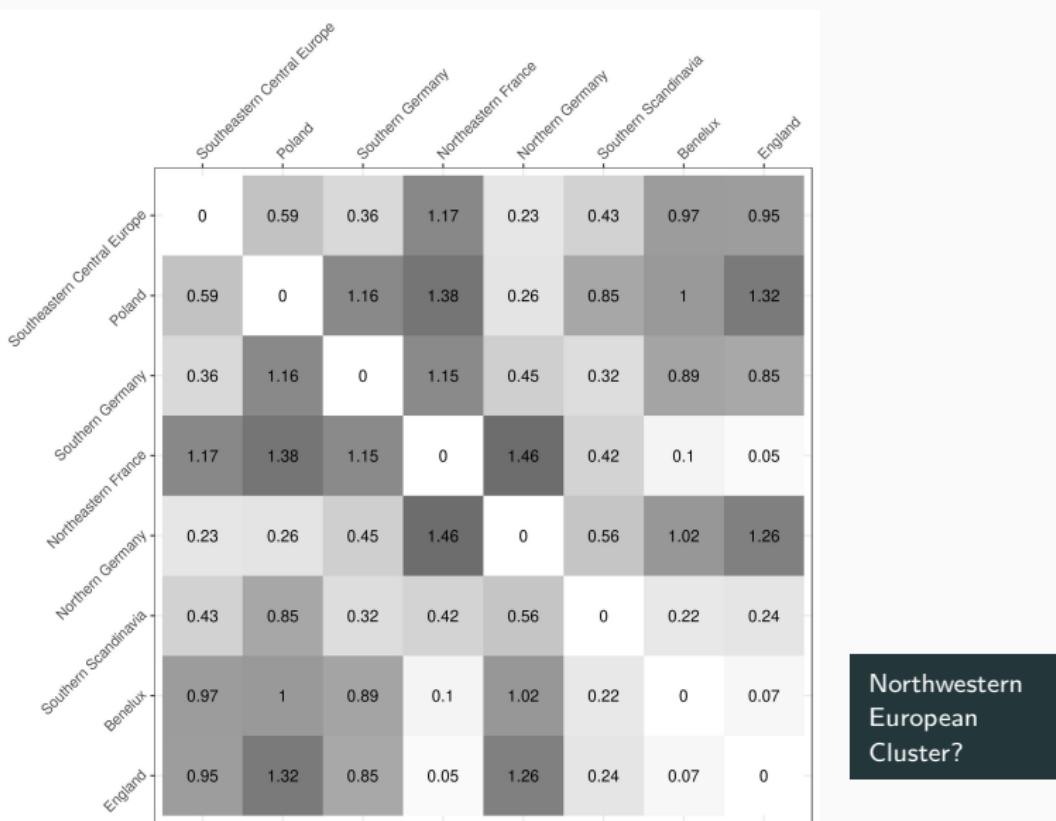
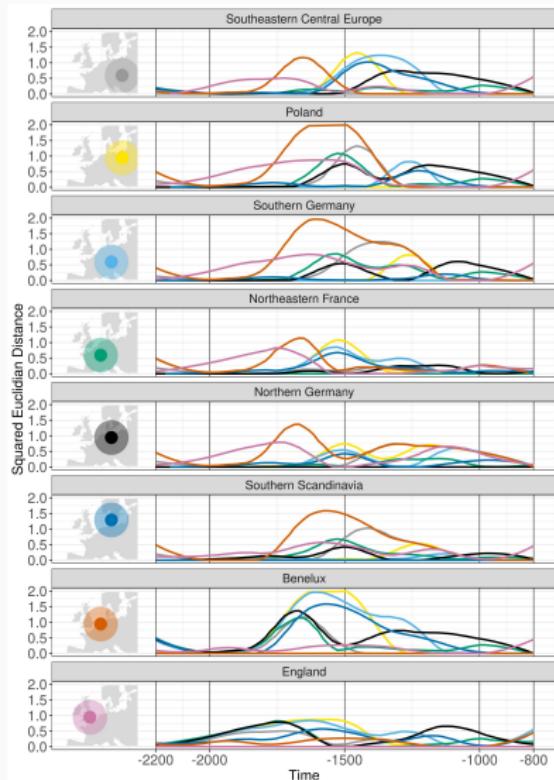
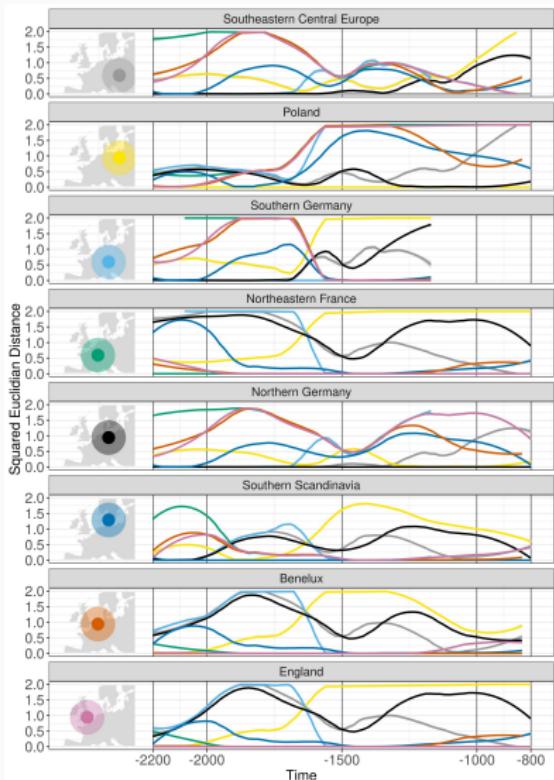


Figure 10: **burial construction:** Mean SED for each region relationship.

# Parallel Developments of Burial Type and Burial Construction Distance?

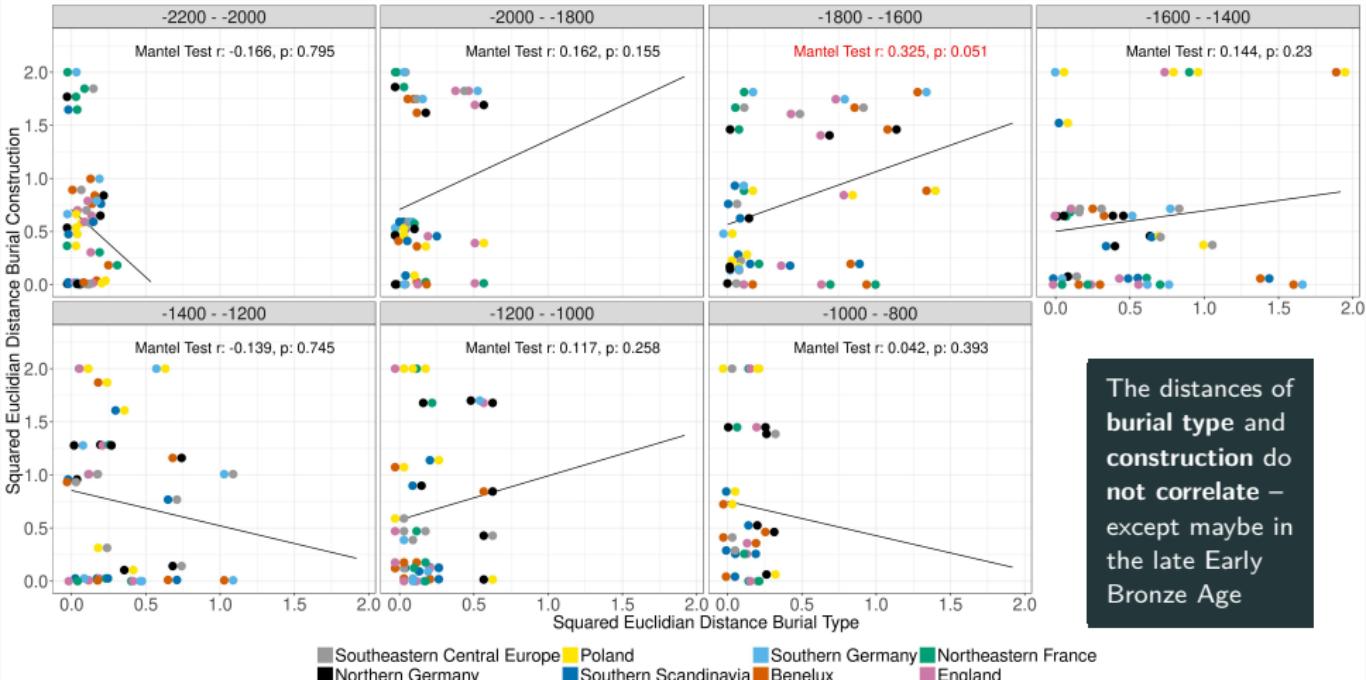


**Figure 11:** burial type Development of SED to all the others for each region.



**Figure 12:** burial construction

# Correlation of Burial Type and Burial Construction Distance



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

**Figure 13:** Correlation of burial type and burial construction mean SED in time slices of 200 years.  
Each double point represents one region-region relationship.

## Cultural and Spatial Distance

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# 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.

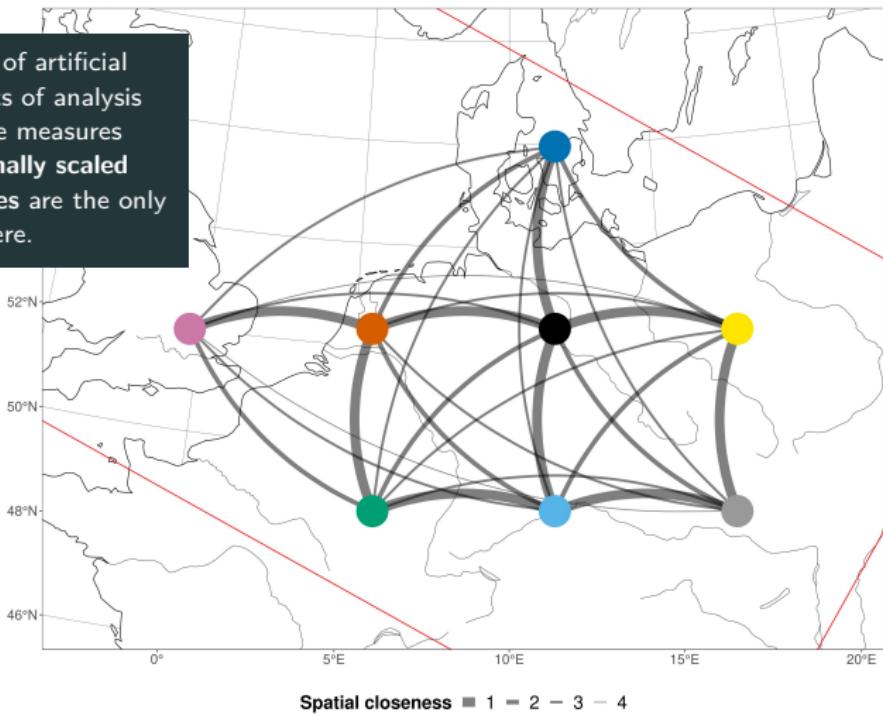


Figure 14: Spatial distance network and definition of distance classes

# Correlation of Burial Type and Spatial Distance

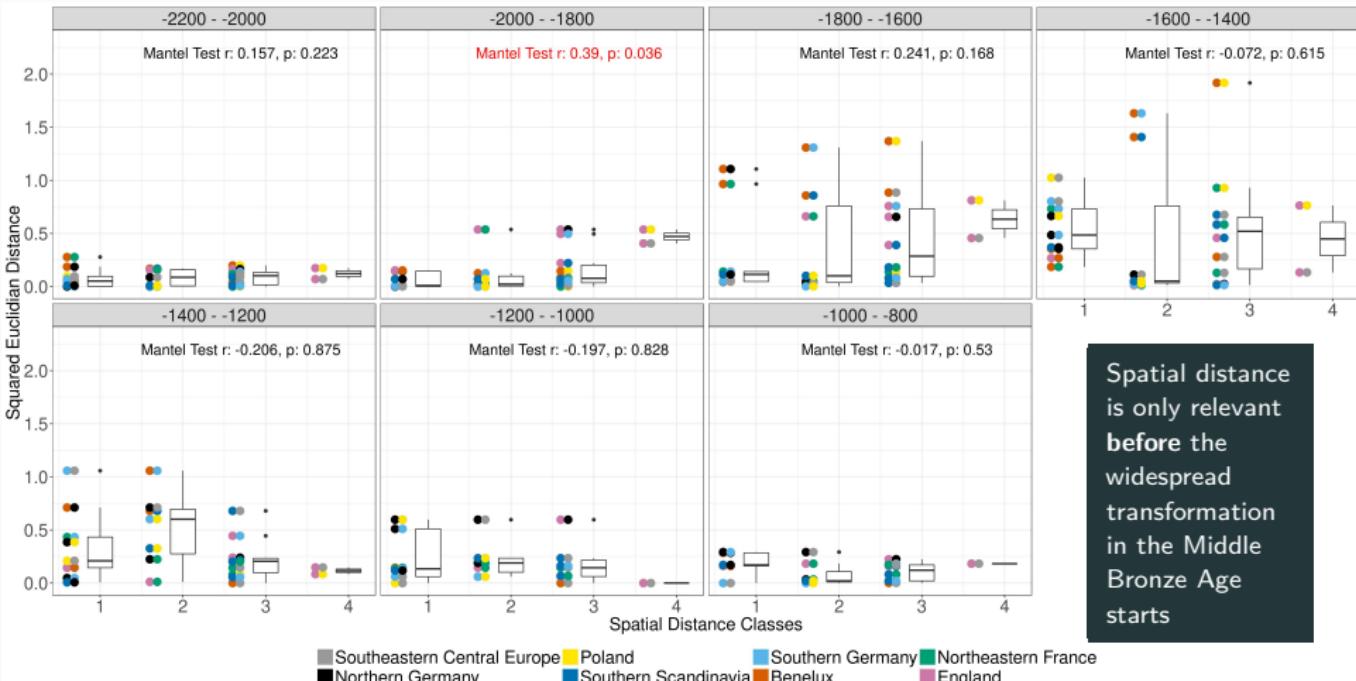
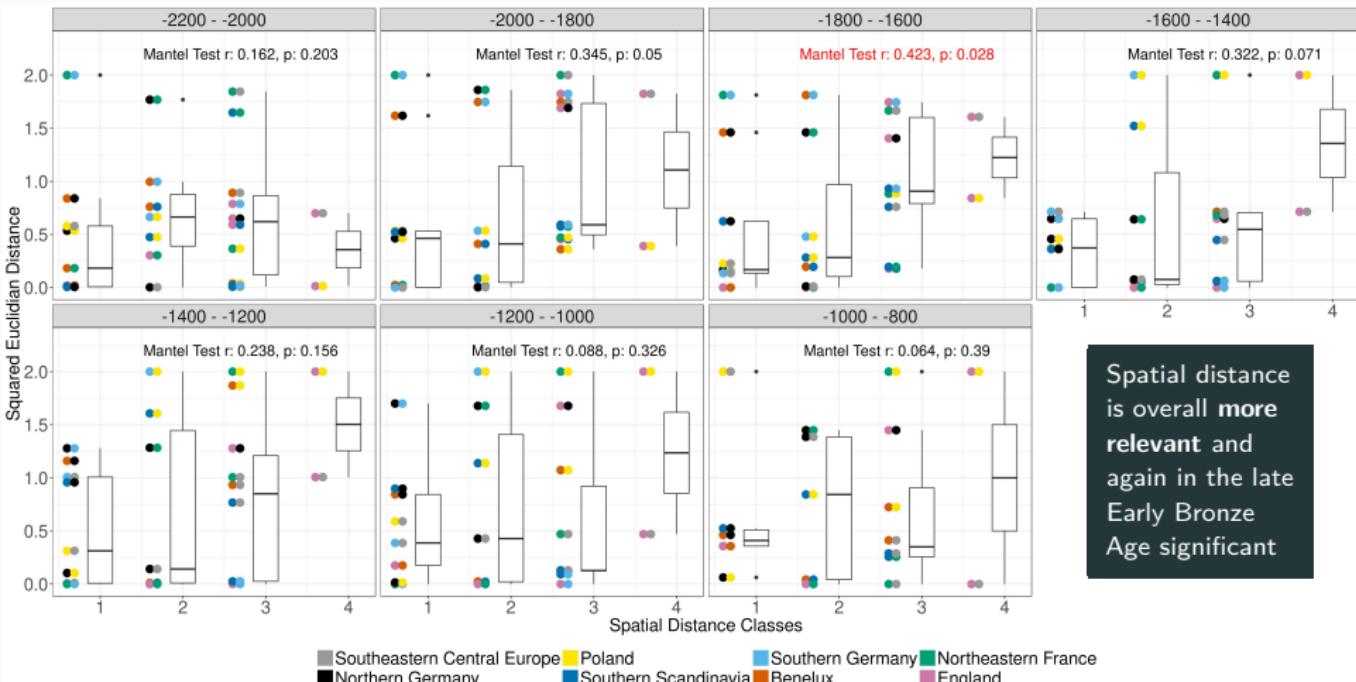


Figure 15: burial type: Correlation of mean SED and spatial distance in timeslices of 200 years.

# Correlation of Burial Construction and Spatial Distance



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

Figure 16: burial construction: Correlation of mean SED and spatial distance in timeslices of 200 years.

## Distance Correlation Summary

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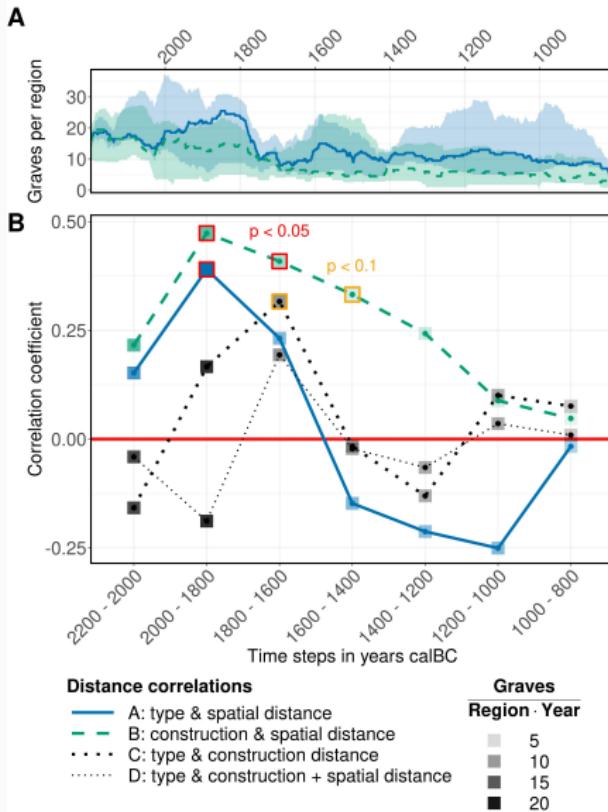
# The complete distance network: Correlation of cultural and spatial distance

C&D: burial type  
& burial  
construction  
distance

No significant  
correlation

B: burial  
construction &  
spatial distance

Weak correlation in  
the EBA, no  
correlation in the  
LBA



**A:** burial type &  
spatial distance

Weak correlation in  
the EBA, negative  
correlation from  
the MBA

**Figure 17:** Time series of cultural and spatial distance correlation. 200 years time slots. Mantel statistics with Pearson correlation coefficient and Spearman's rank correlation.

## Simulation

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## 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**.

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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**.

The main mechanisms of diffusion of neutral variants are **innovation, drift** and **flow**.

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

Simulation concept:

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

# Population Graph Creation

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

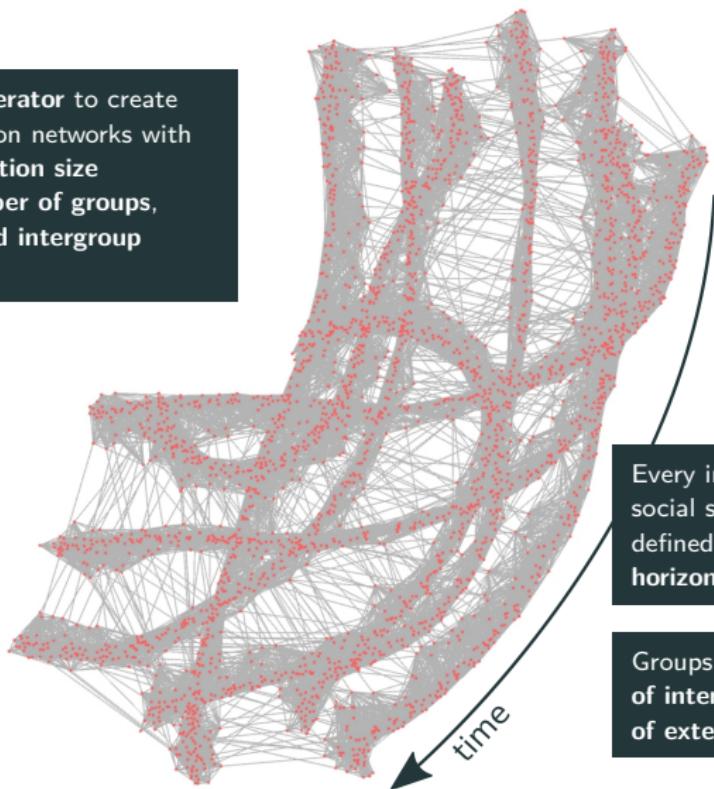


Figure 18: Example Population Graph. Arranged with the Fruchterman & Reingold algorithm.

# 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** `gluesless` 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?

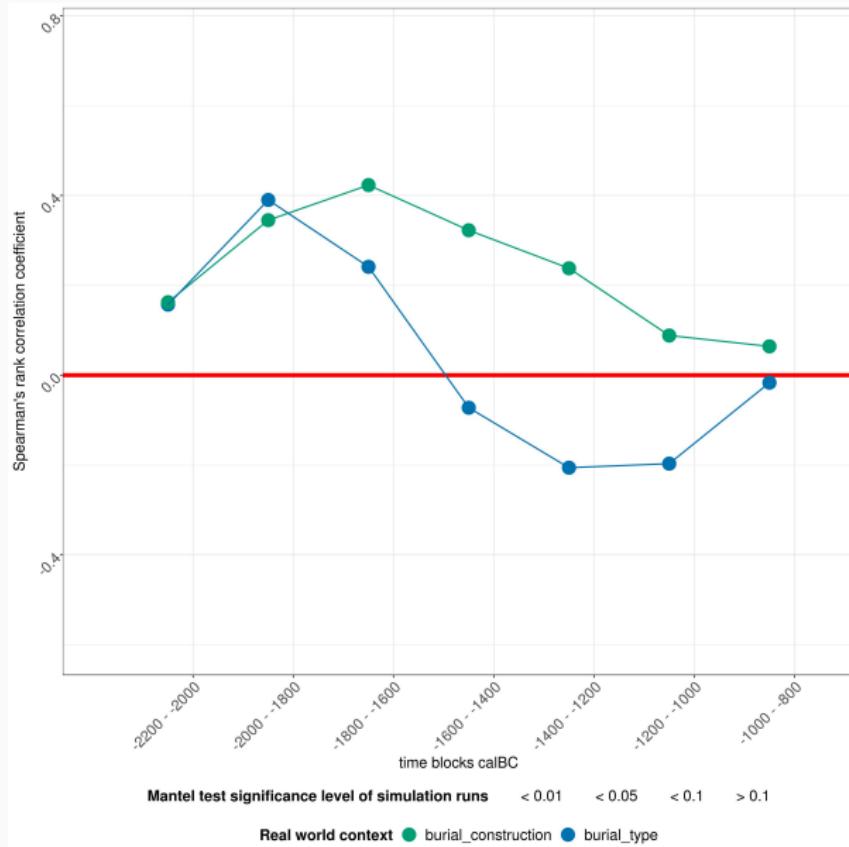


Figure 19: Correlation of cultural and spatial distance over time for **real world observations**.

# Simulation Application: Correlation of Spatial and Cultural Distance

Can  
correlation of  
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ruled out?

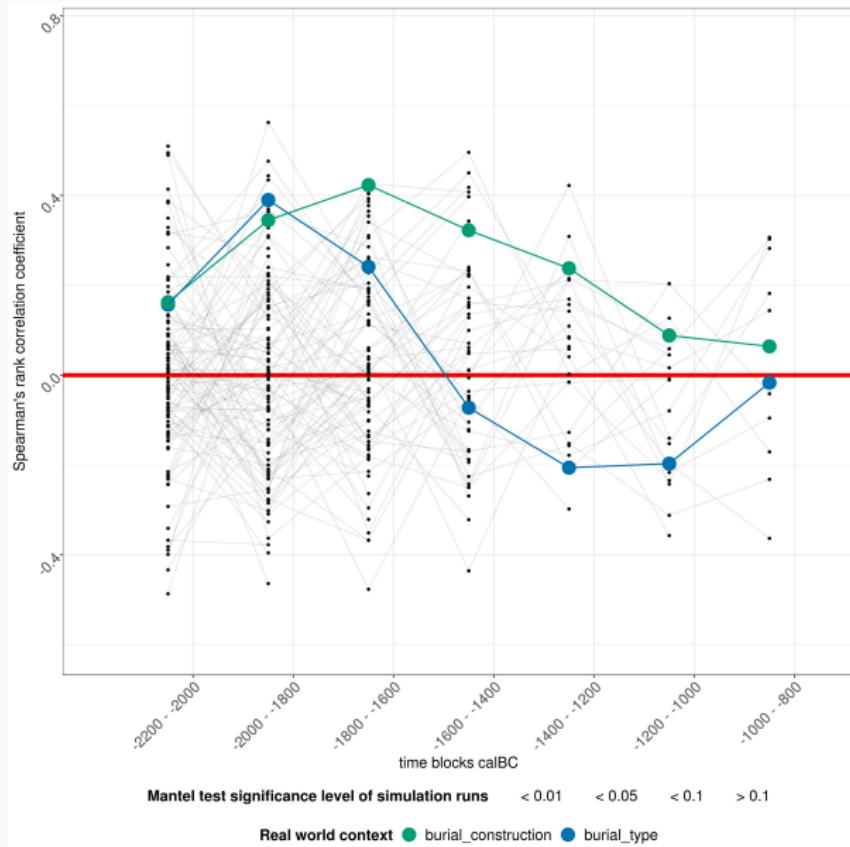


Figure 20: + Correlation development for 100 simulation runs with equal intergroup distance.

# 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

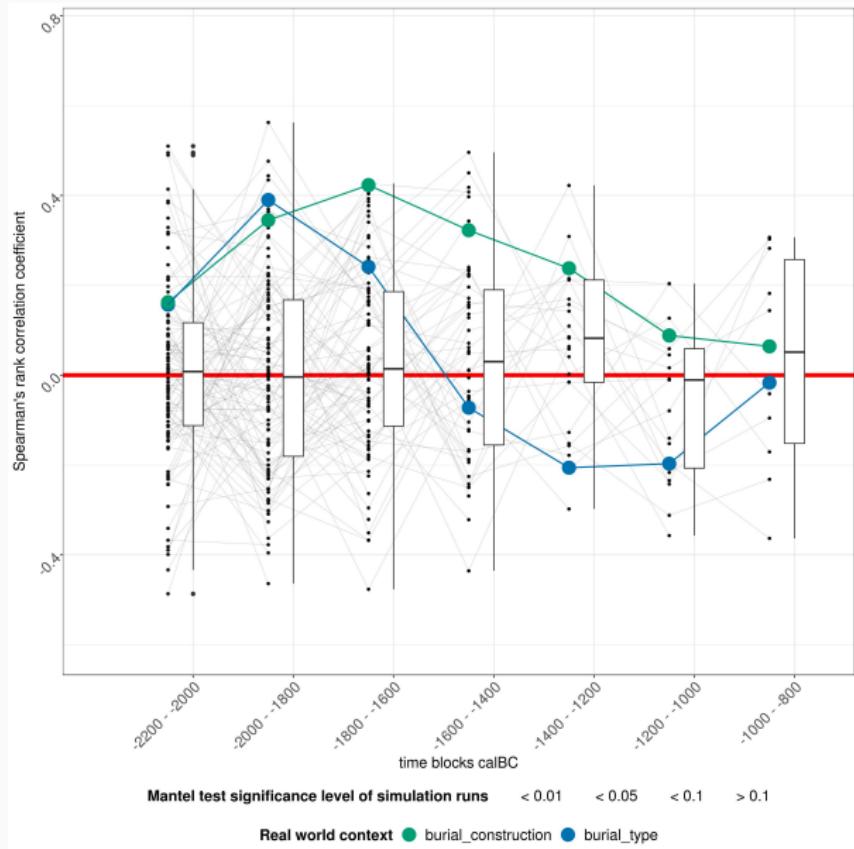


Figure 21: + Diagnostic boxplots for simulation runs.

# Simulation Application: Correlation of Spatial and Cultural Distance

Can  
correlation of  
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Equal  
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Unlikely  
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Bronze Age

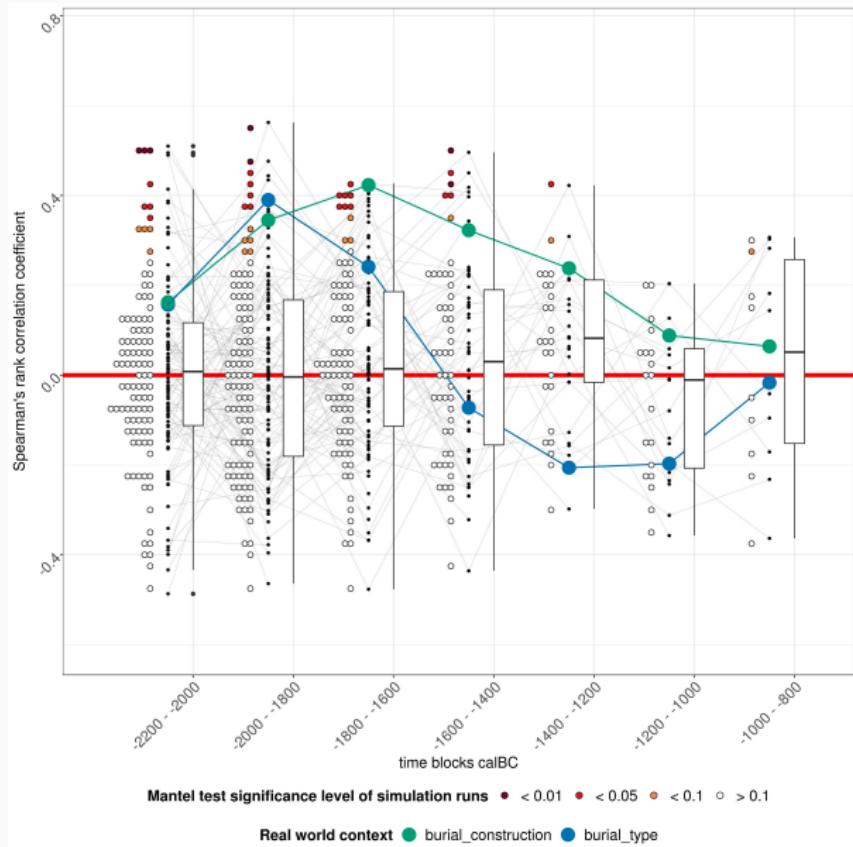


Figure 22: + Diagnostic dotplots indicating mantel test results.

# 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

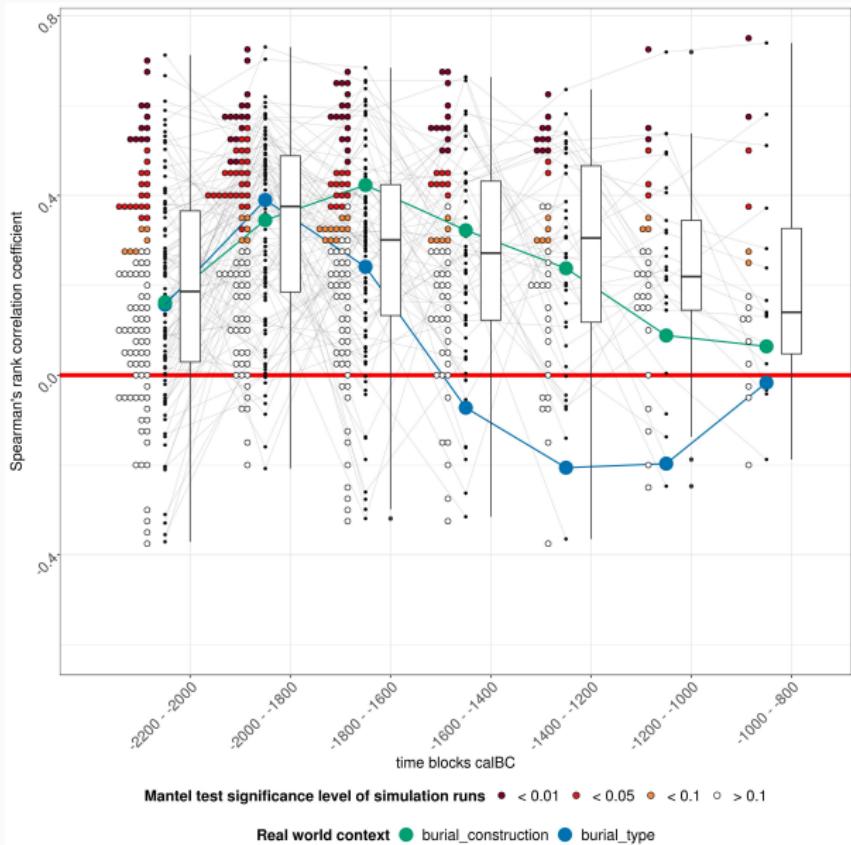


Figure 23: Same plot, but simulations now with spatial intergroup distance.

## Conclusion

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## Observations and Hypotheses

- The **main trends** in the distribution of burial rites in Bronze Age Europe can be detected in **bulk radiocarbon data**
- The diffusion of the **cremation funeral tradition** and **traditions of flat vs. mound graves** are **mostly independent**
- Both processes are **mostly independent of spatial distance**, except for some time periods in the Early Bronze Age
- **Big phenomena** like the ones initiated by **Tumulus culture** and **Urnfield culture** do not spread in simple diffusion processes
- **Other interaction networks** could yield better predictions: Elite Networks, Religious superstructures, ...

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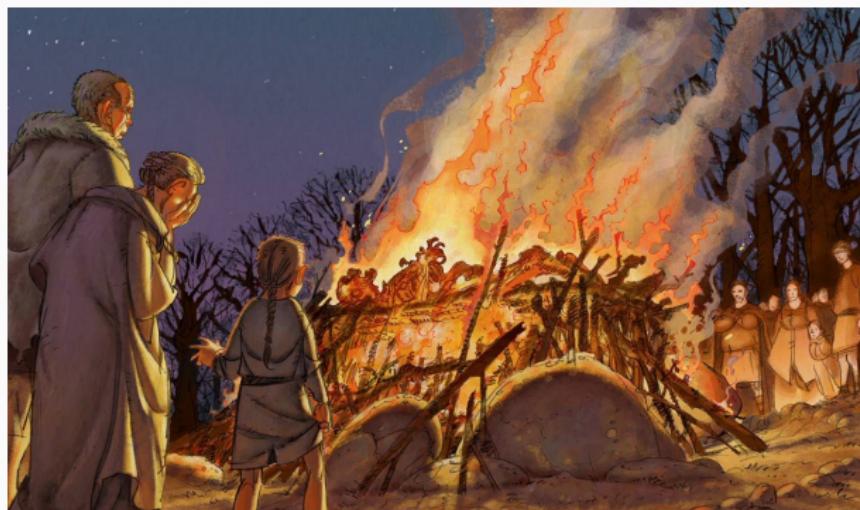
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