

# 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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Clemens Schmid

@nevromeCS

github.com/nevrome

clemens@nevrome.de

Supervisors at  
Kiel University:  
PD Dr. Oliver Nakoinz  
Dr. Martin Hinz

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

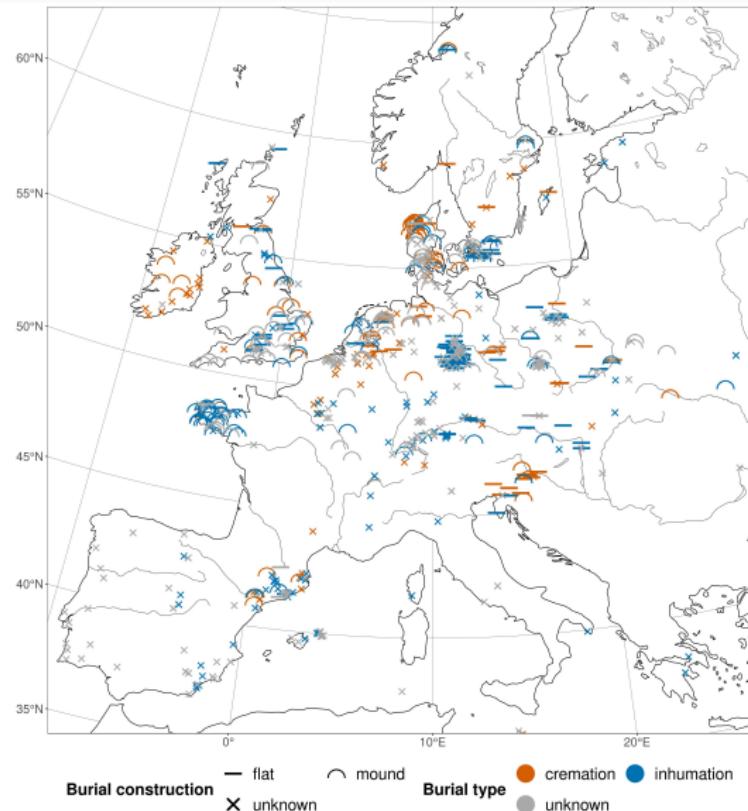
## **Introduction**

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# Data

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

Radiocarbon  
dating is one of  
the most  
important  
absolute dating  
methods: One  
date equals a  
fuzzy point in  
space and time  
with context  
information



Metainformation  
for dates from  
graves: **burial  
type & burial  
construction**

Heterogeneous  
information  
density in space  
and time

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

# Research Area and Regions

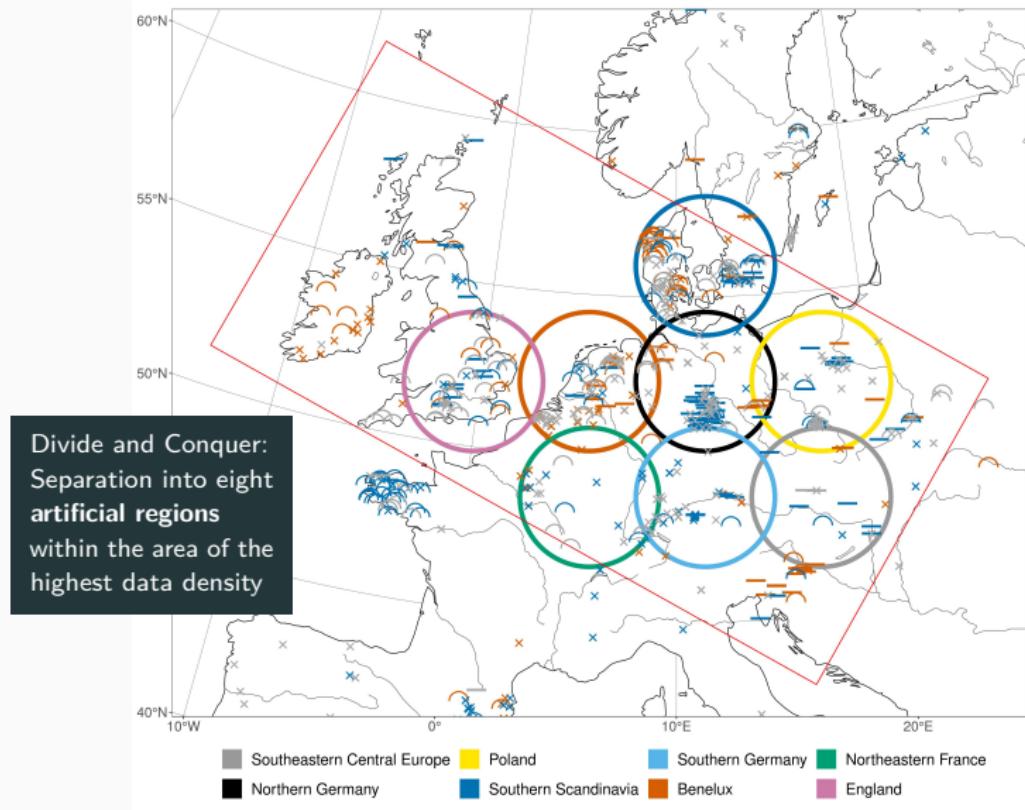
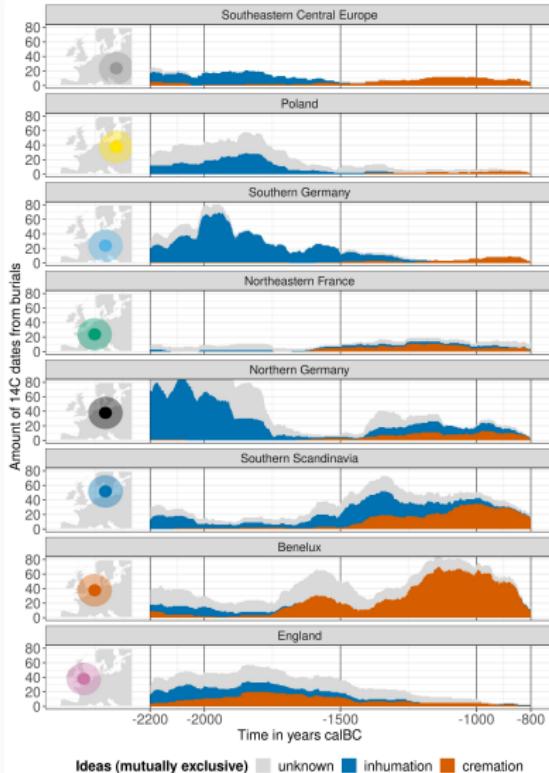
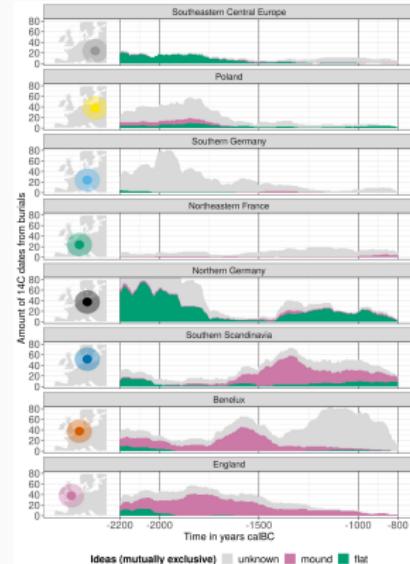


Figure 2: Artificial Regions: 400km distance, 240km radius,  $\geq 70$  dates.

# Development – Absolute Numbers



**Figure 3: burial type development:** Sum of  $^{14}\text{C}$  dates whose  $2\sigma$  range cover the respective year.



**Figure 4: burial construction**

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

# Development – Proportions

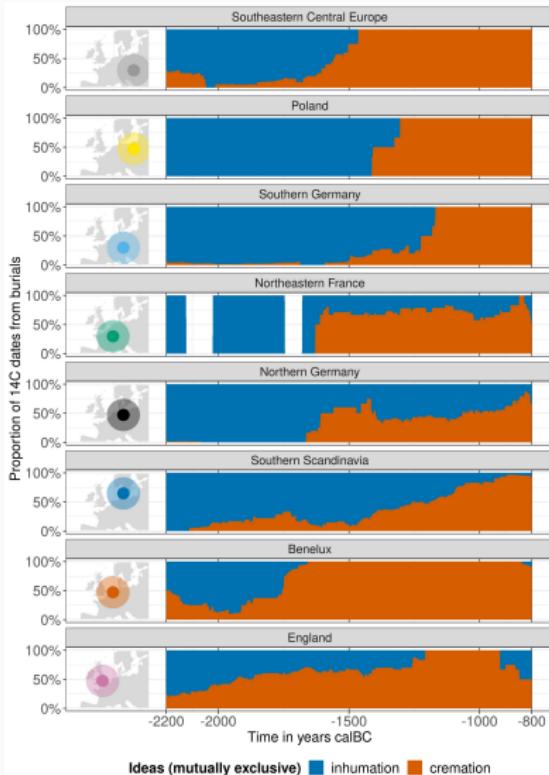


Figure 5: burial type development: Year wise proportions of dates. *unknown* is filtered out.

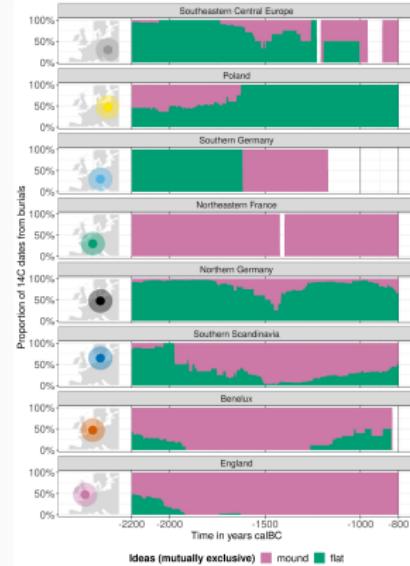


Figure 6: burial construction

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

## **Cultural Distance**

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## 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?

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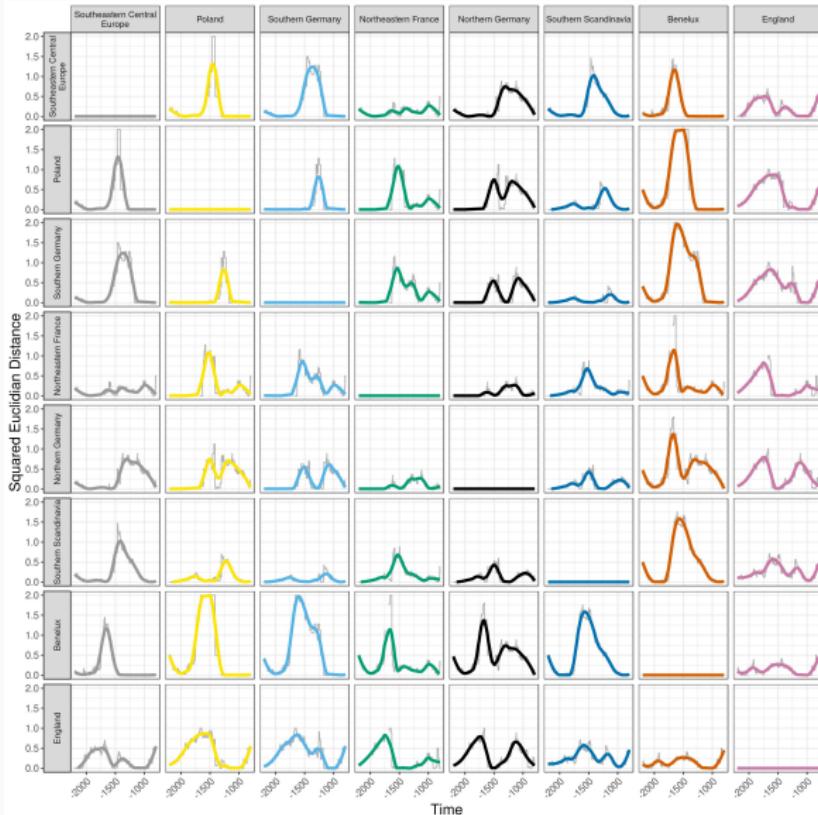
The **Squared Euclidian Distance** is a simple measure of between-group similarity that can be applied to the **burial rite proxy** data.

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

- $d_{ij}^2$ : 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

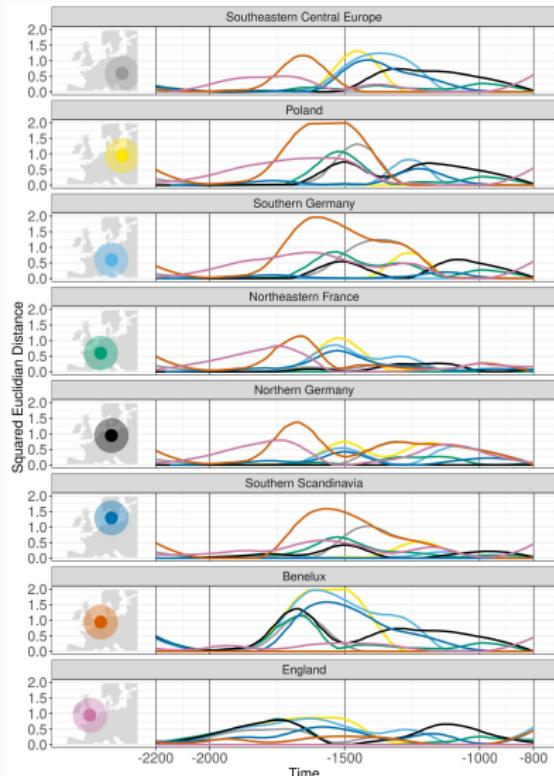


Low distance at the start and end due to the universal shift from inhumation to cremation with rise of the Urnfield culture

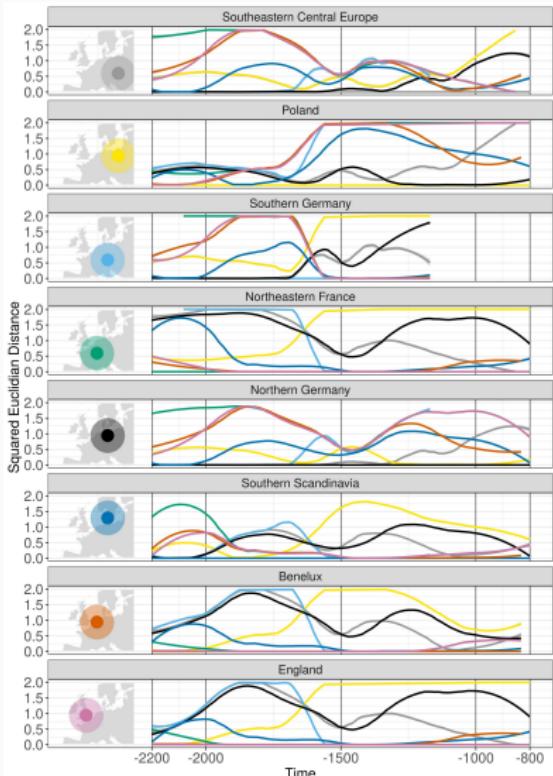
The different adoption rates are visible as peaks of cultural distance

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

# Parallel Developments?

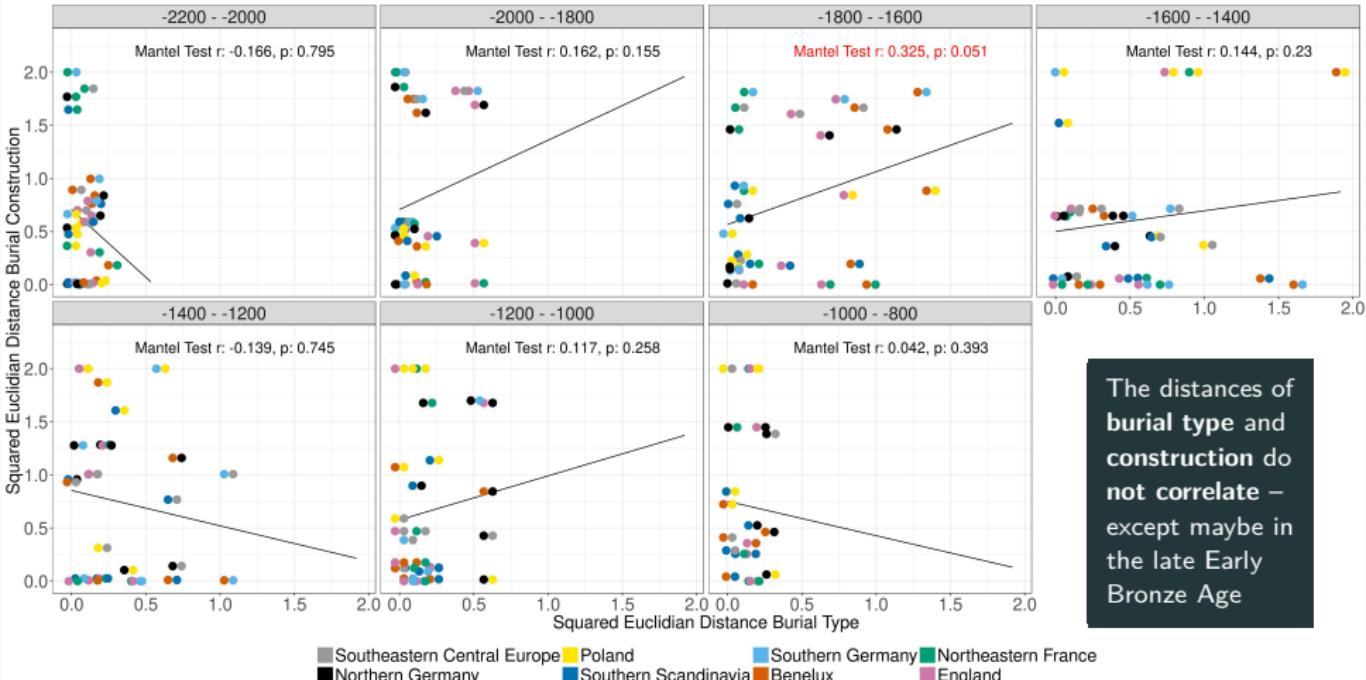


**Figure 8: burial type** Development of SED to all the others for each region.



**Figure 9: burial construction**

# Correlation of Burial Type and Burial Construction Distance



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

**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.

## **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.

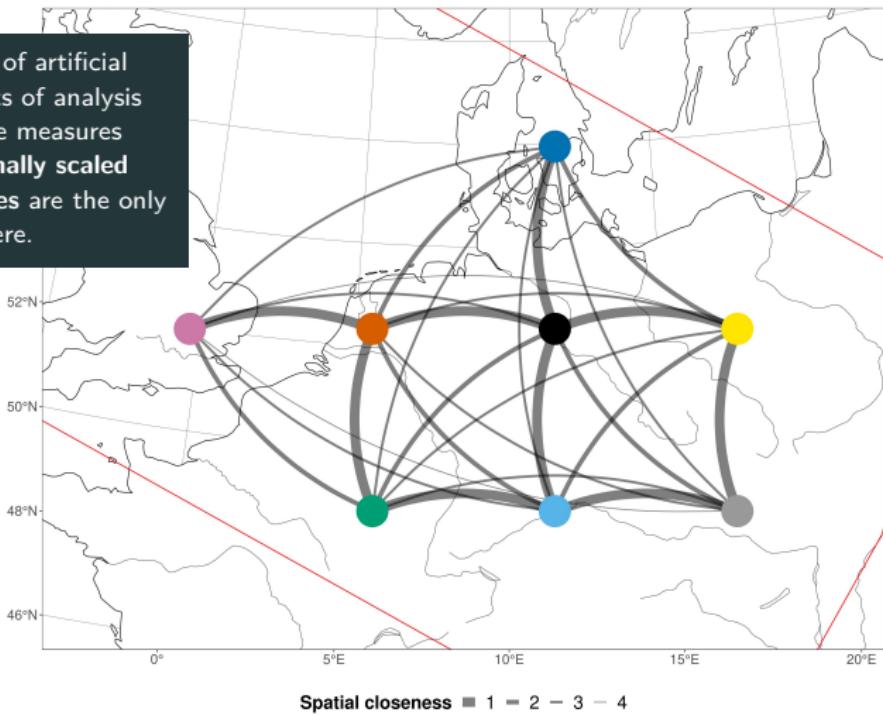


Figure 11: Spatial distance network and definition of distance classes

# Correlation of Burial Type and Spatial Distance

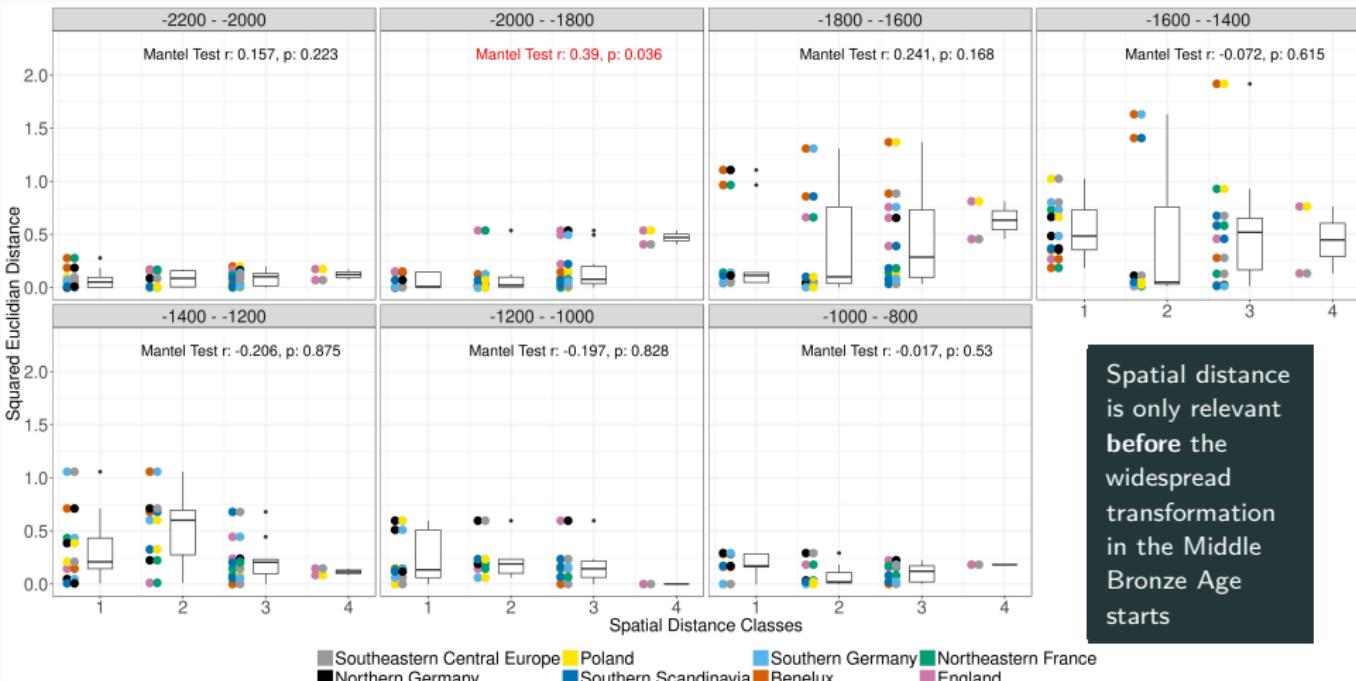
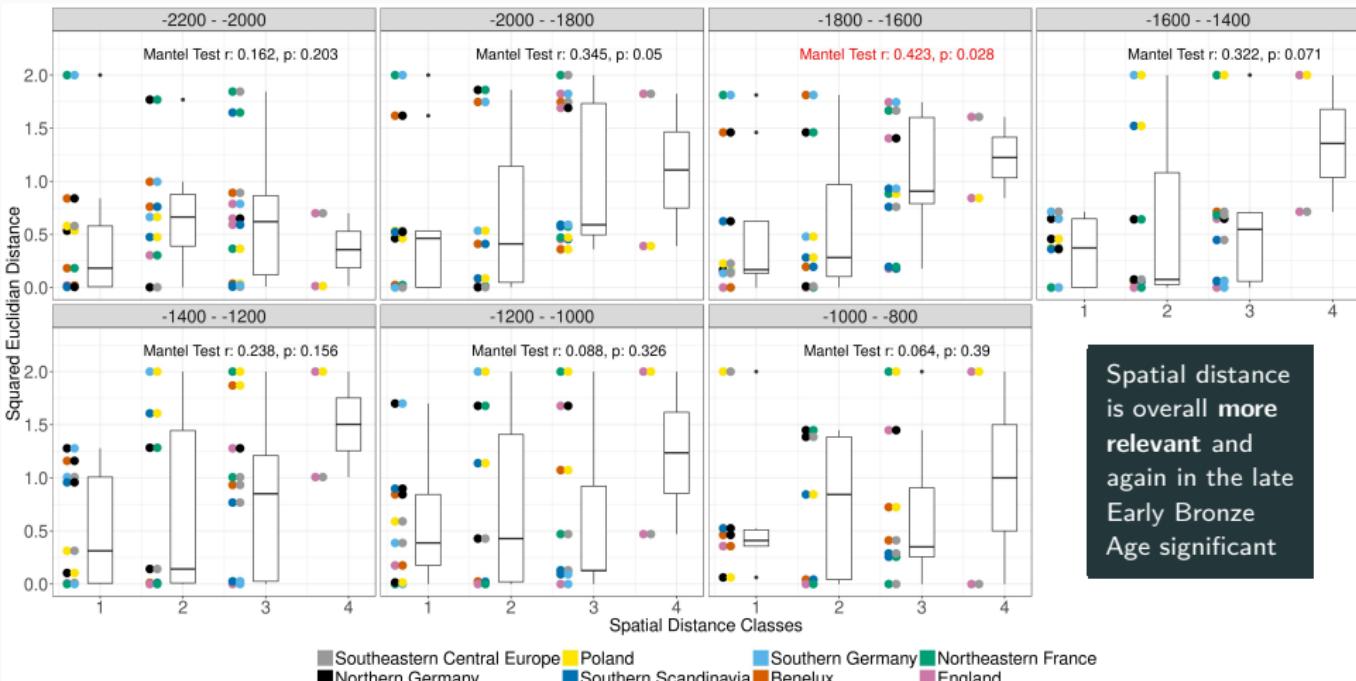


Figure 12: burial type: Correlation of mean SED and spatial distance in timeslices of 200 years.

# 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

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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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Simulation concept:

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

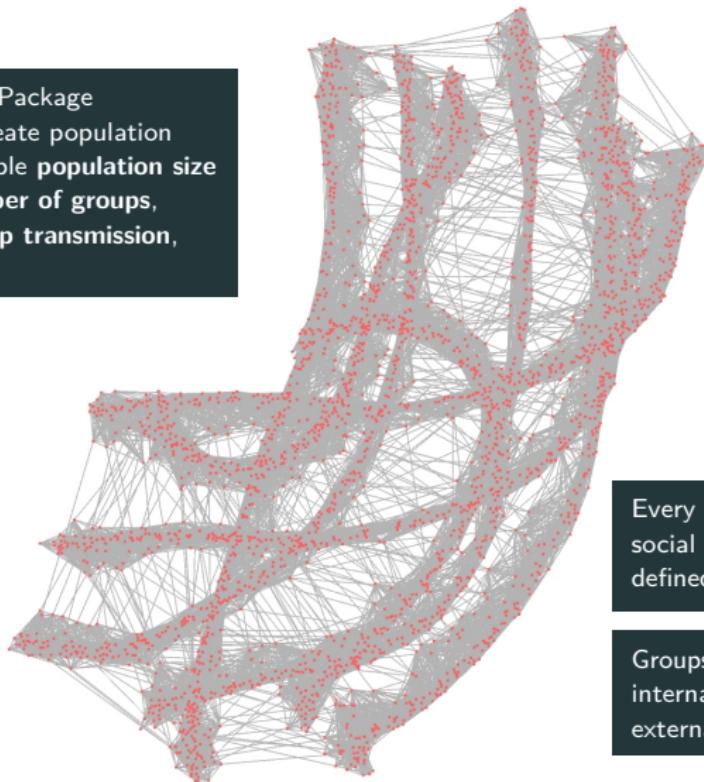
Funeral rituals are a special category of ideas: They have a relatively low interaction with the human-environment system and can be treated as **selectively neutral**. [Dunnell 1978]

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

- **Drift:** Dominance of individual traits due to stochastic processes
- **Flow:** Information transfer and synchronization across group boundaries

# Population Graph Creation

Implementation: R Package  
**popgenerator** to create population networks with variable **population size**, **development**, **number of groups**, **degree of intergroup transmission**, etc.



Every individual's position in social space and time is defined by their connections

Groups have a high degree of internal and a low degree of external interaction

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);
}
...

```

Implementation: C++ CLI program  
**gluesless** to simulate idea expansion  
within the population network

# Simulation Application: Correlation of Spatial and Cultural Distance

Is correlation  
of spatial and  
cultural  
distance still  
plausible?

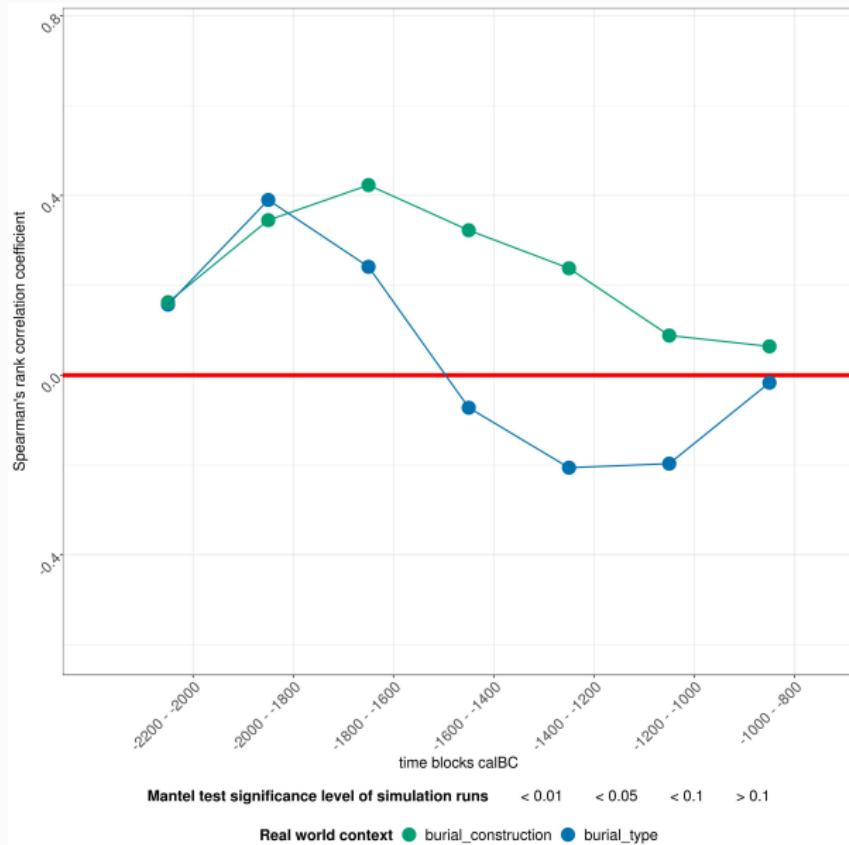


Figure 15: Correlation of cultural and spatial distance over time for **real world observations**.

# Simulation Application: Correlation of Spatial and Cultural Distance

Is correlation  
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plausible?

Simulation  
results in  
comparison  
with real world  
data

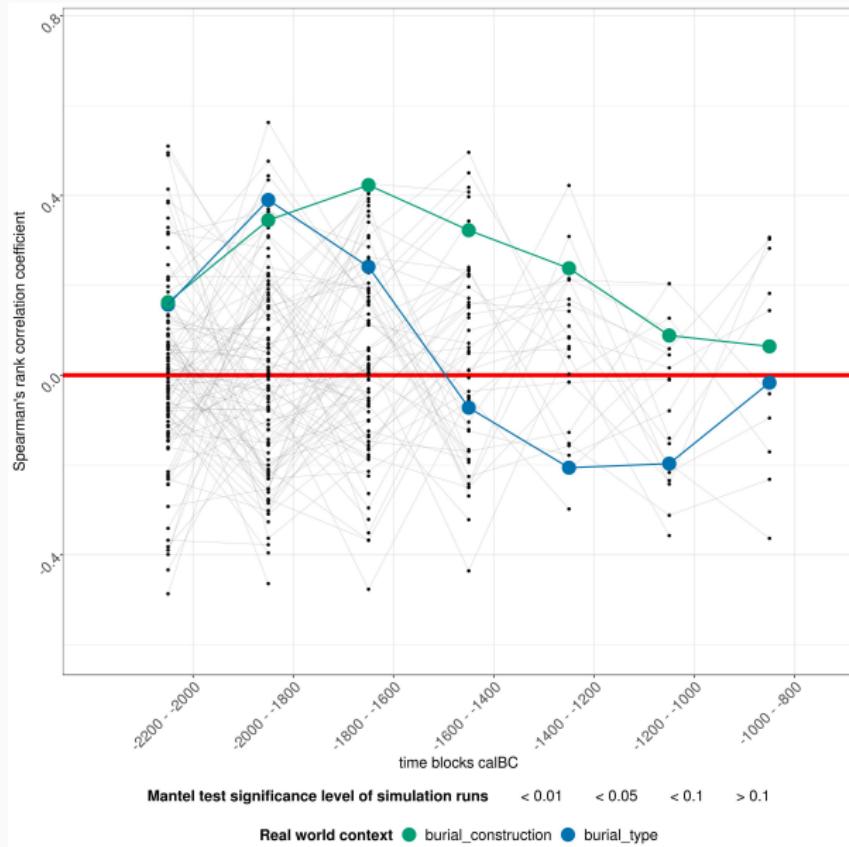


Figure 16: + Correlation development for 100 simulation runs with equal intergroup distance.

# Simulation Application: Correlation of Spatial and Cultural Distance

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Simulation  
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The real world  
correlation is  
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the spectrum  
of equal  
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simulations

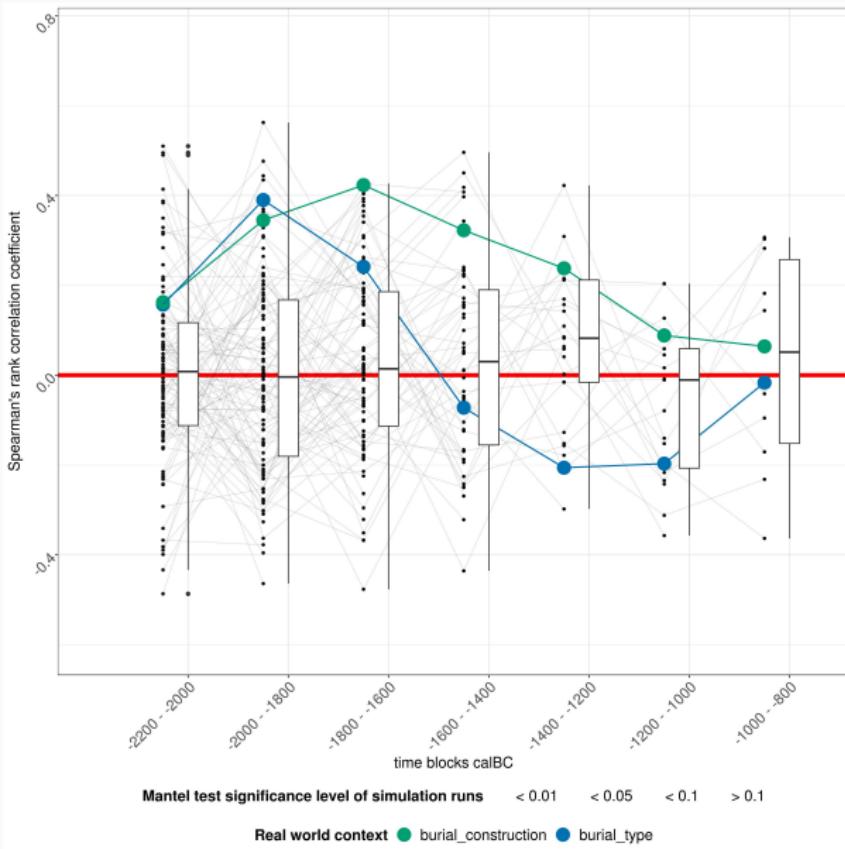


Figure 17: + Diagnostic boxplots for simulation runs.

# Simulation Application: Correlation of Spatial and Cultural Distance

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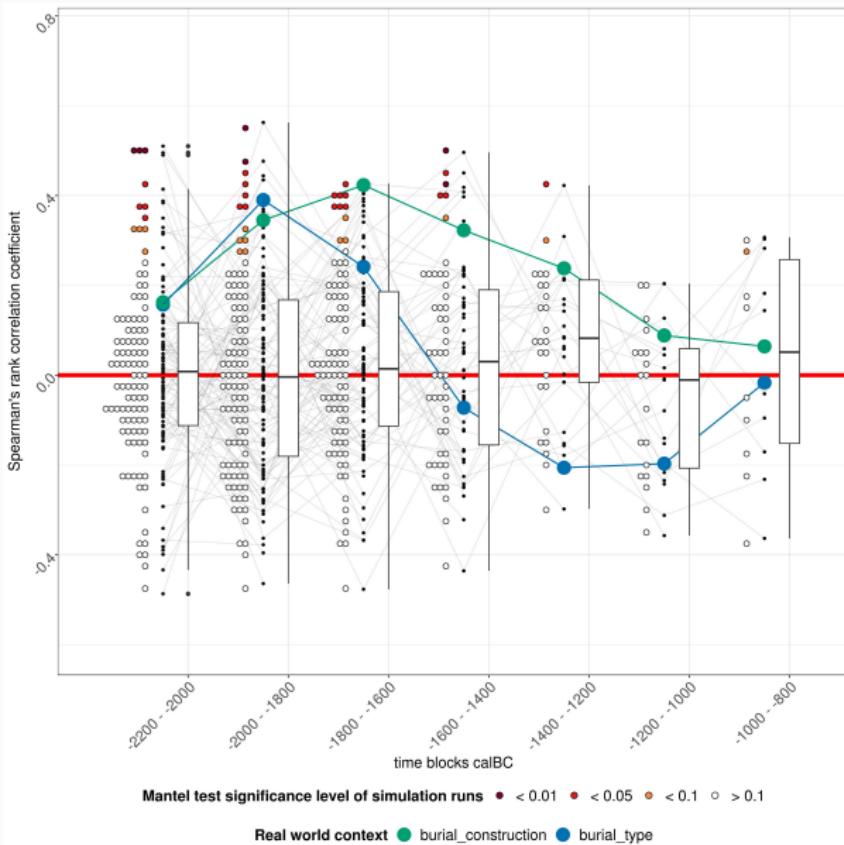


Figure 18: + Diagnostic dotplots indicating mantel test results.

# Simulation Application: Correlation of Spatial and Cultural Distance

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Spatial  
intergroup  
distance in the  
population  
graph increases  
correlation

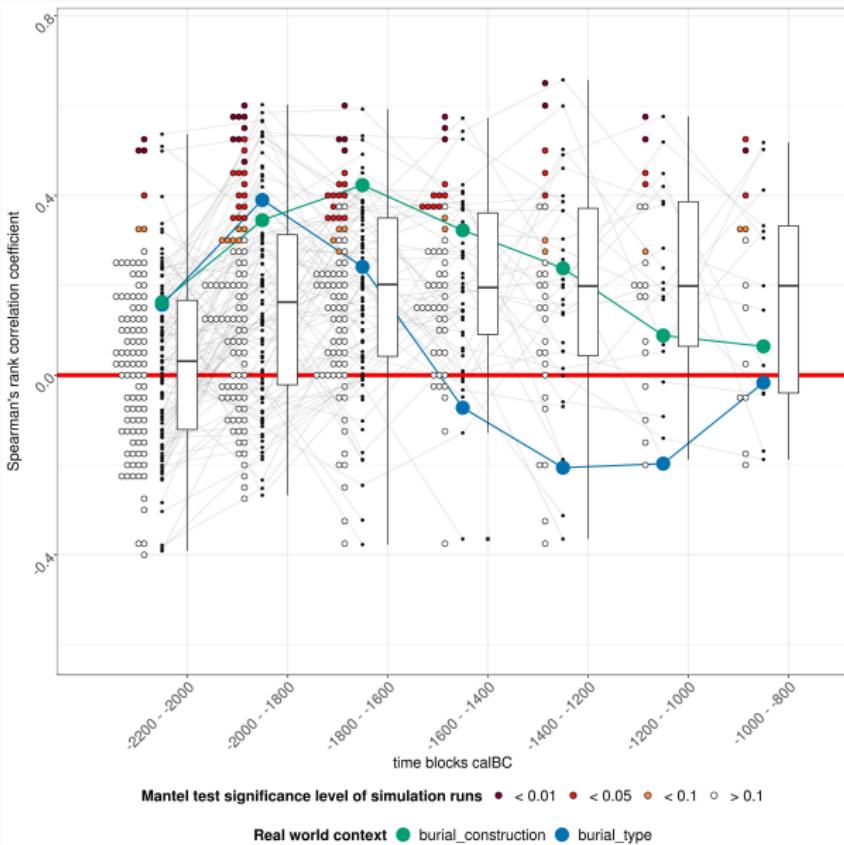


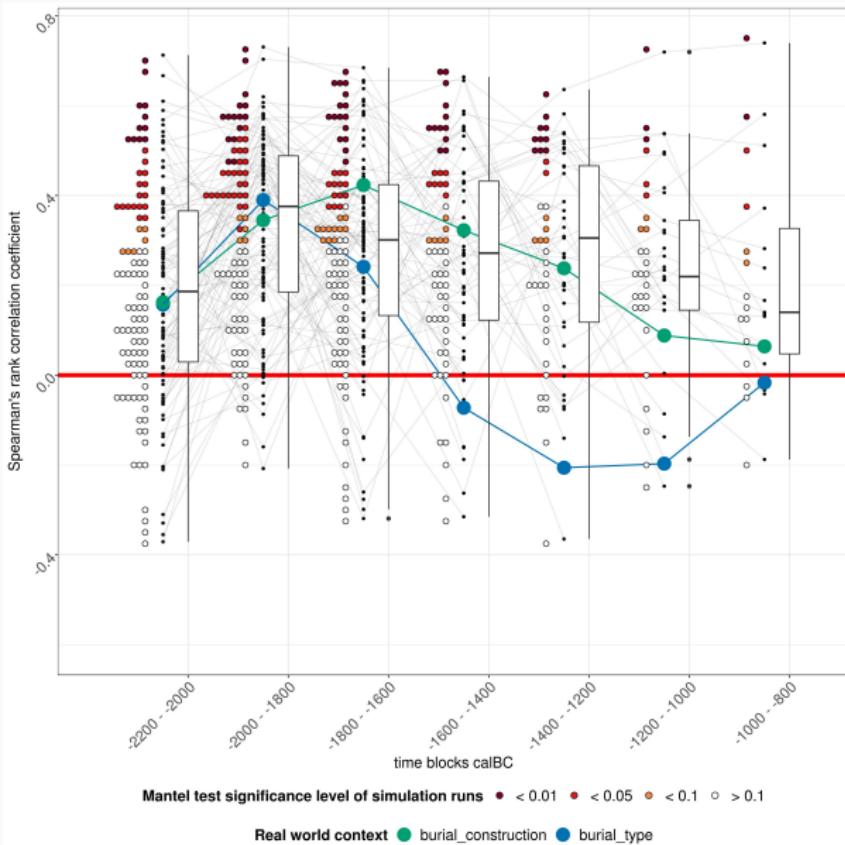
Figure 19: Same plot, but simulations now with low spatial intergroup distance.

# Simulation Application: Correlation of Spatial and Cultural Distance

Is correlation  
of spatial and  
cultural  
distance still  
plausible?

Simulation  
results in  
comparison  
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data

The real world  
correlation is  
mostly within  
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of equal  
intergroup  
distance  
simulations



Spatial  
intergroup  
distance in the  
population  
graph increases  
correlation

Generally more  
interaction  
increases  
correlation

Compared to  
simulation  
results the  
expansion of  
cremation  
behaves highly  
atypical if we  
assume spatial  
correlation

Figure 20: Same plot, but simulations now with **high** spatial intergroup distance.

## Conclusion

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## Observations and Hypotheses

- The diffusion of the cremation funeral tradition and traditions of flat vs. mound graves are mostly **independent**, except for a short period in the late Early Bronze Age.
- Both contexts are to a certain degree correlated to **spatial distance** in the Early Bronze Age, but become **increasingly unpredictable** in the Middle Bronze Age.
- Both contexts can be explained by **neutral variant drift and flow** on a large scale. Local innovation might not have been necessary.
- **Sociocultural complexity** in the Bronze Age is generally **increasing**. Still the **homogeneity & heterogeneity** of certain cultural traits **vary greatly**.