

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

Introduction

Data

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

Metainformation
for dates from
graves: burial
type & burial
construction

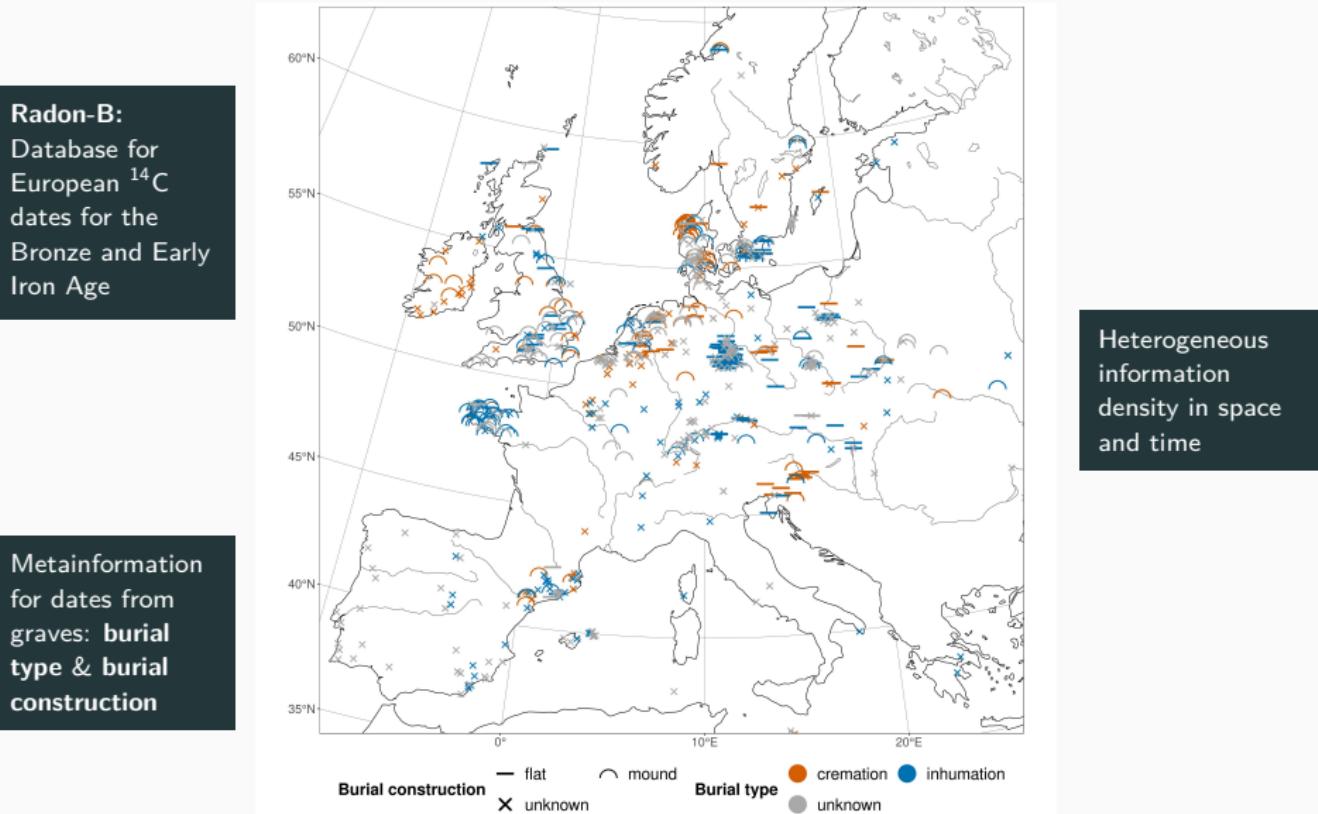


Figure 1: Radon-B ^{14}C dates of graves 2200-800 calBC (Albers Equal Area Conic).

Research Area and Regions

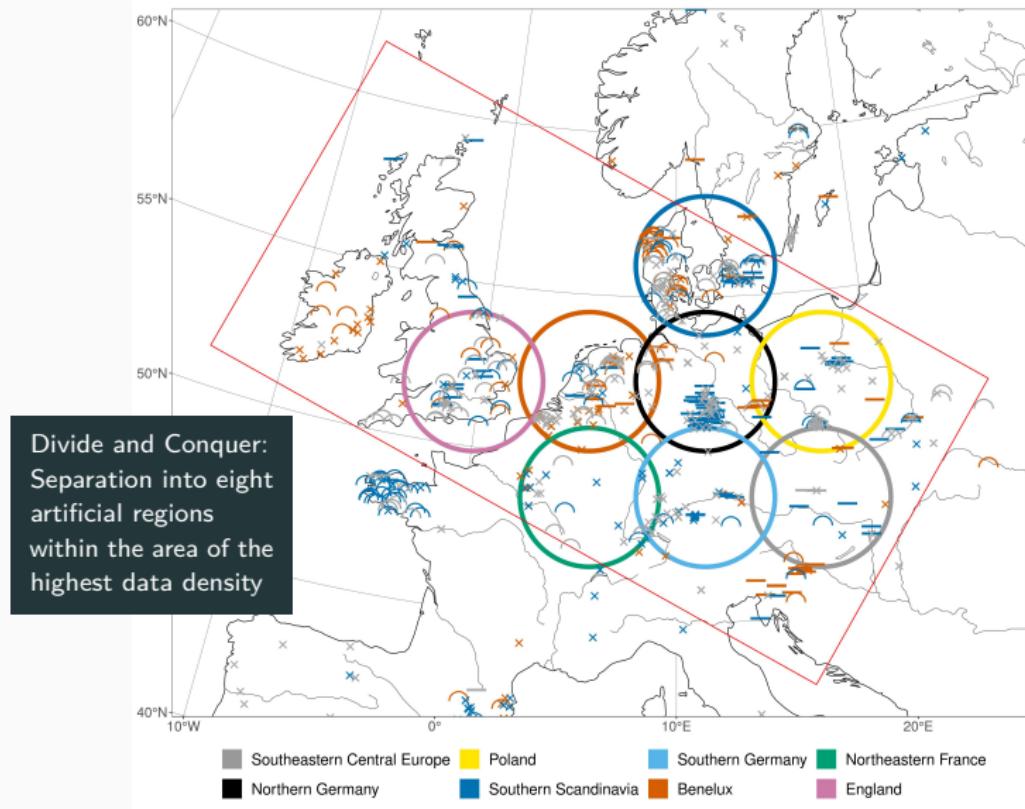


Figure 2: Artificial Regions: 400km distance, 240km radius, ≥ 70 dates.

Development – absolute numbers

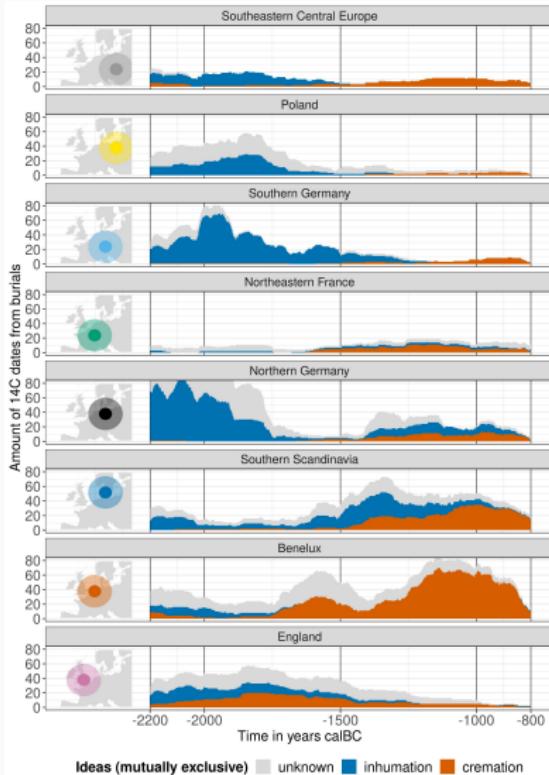


Figure 3: burial type development: Sum of ^{14}C dates whose 2σ range cover respective year.

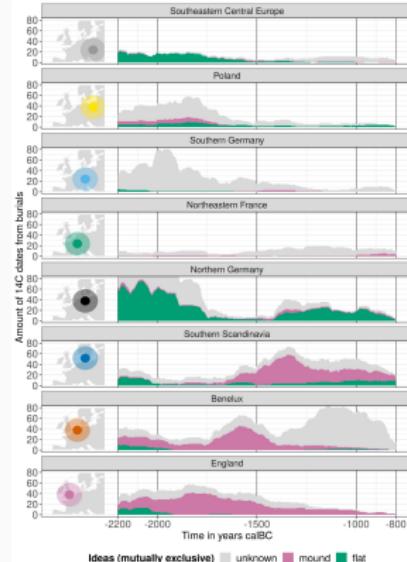


Figure 4: burial construction

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

Development – proportions

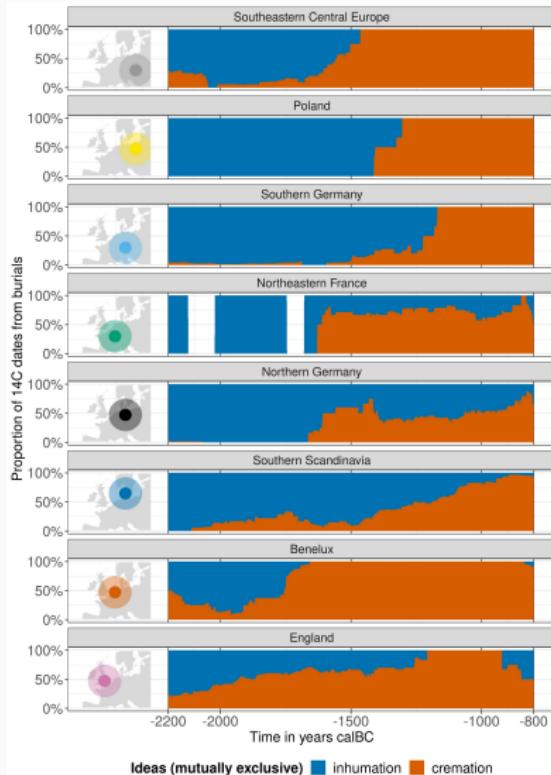


Figure 5: burial type development: Year wise proportions of dates. *unknown* is filtered out.

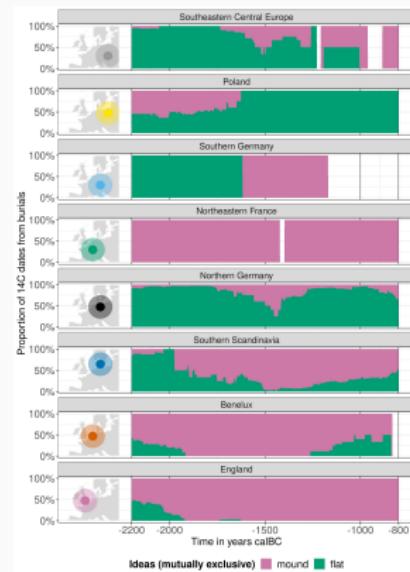


Figure 6: burial construction

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?

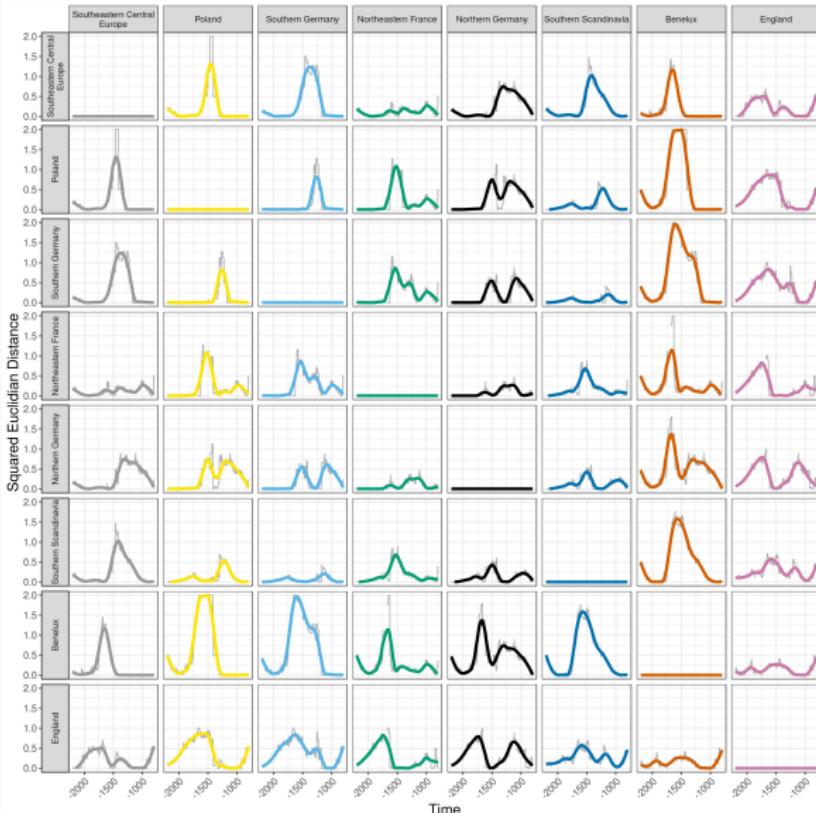
The **Squared Euclidian Distance** is a simple measure of between-group similarity that can be applied to the **burial rite proxy** data.

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

- 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



The different adoption rates are visible as peaks of cultural distance

Low distance at the start and end due to universal shift from inhumation to cremation

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

Mean Region-Region Distance Matrix

Central
European
Cluster?

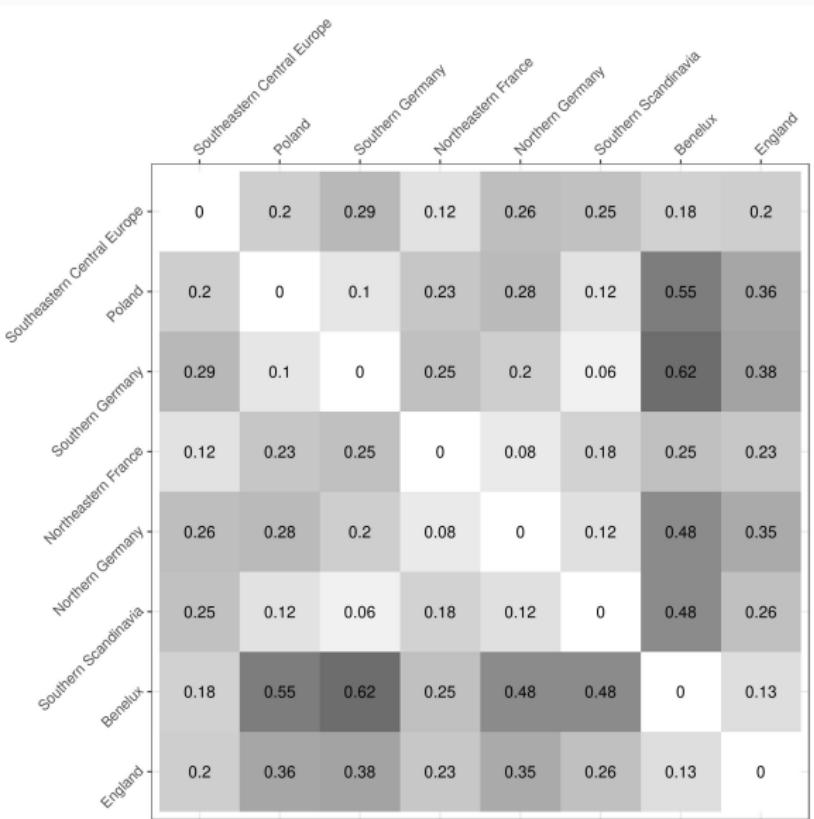
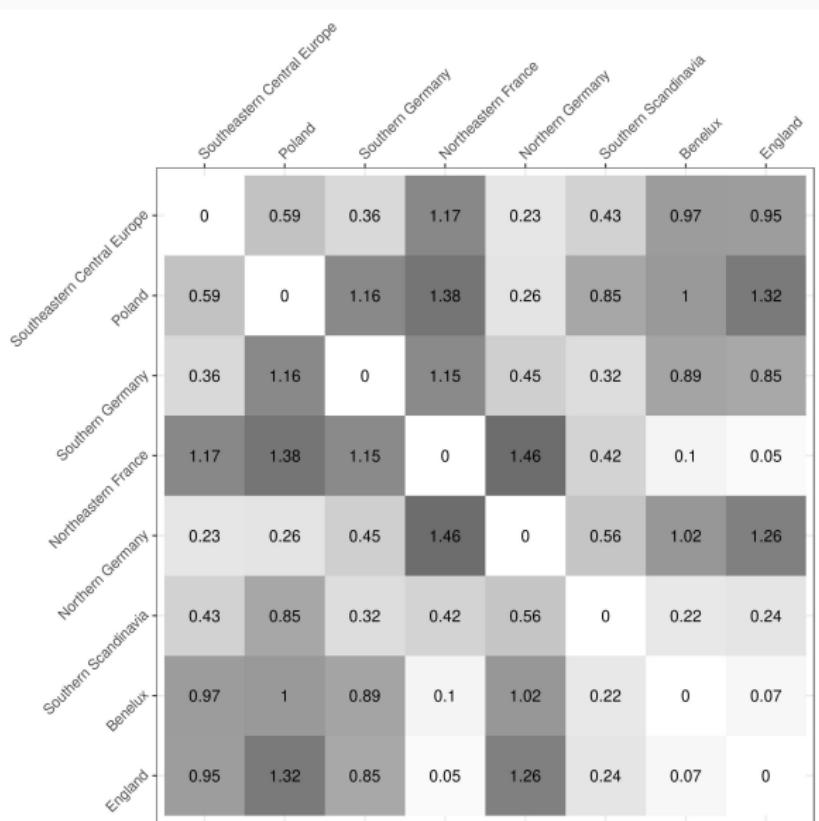


Figure 8: burial type: Mean SED for each region relationship. The lower, the closer.

Mean Region Distance Matrix



Northwestern
European
Cluster?

Figure 9: burial construction: Mean SED for each region relationship.

Parallel Developments?

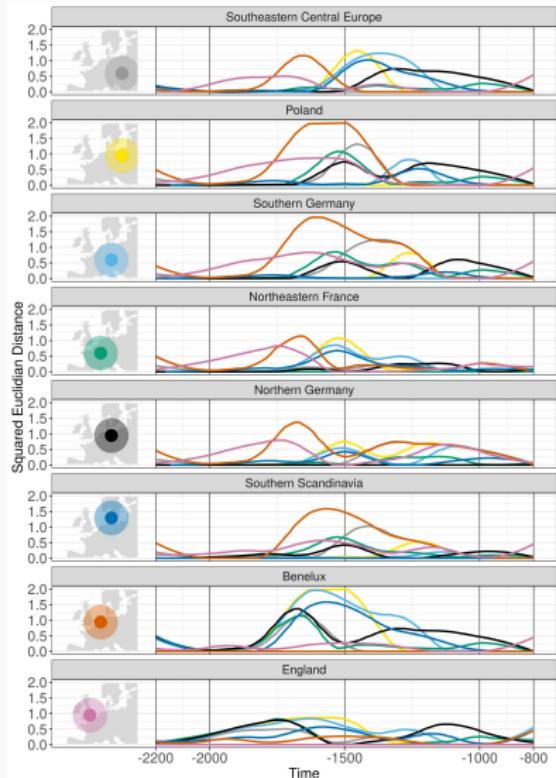


Figure 10: burial type Development of SED to all the others for each region.

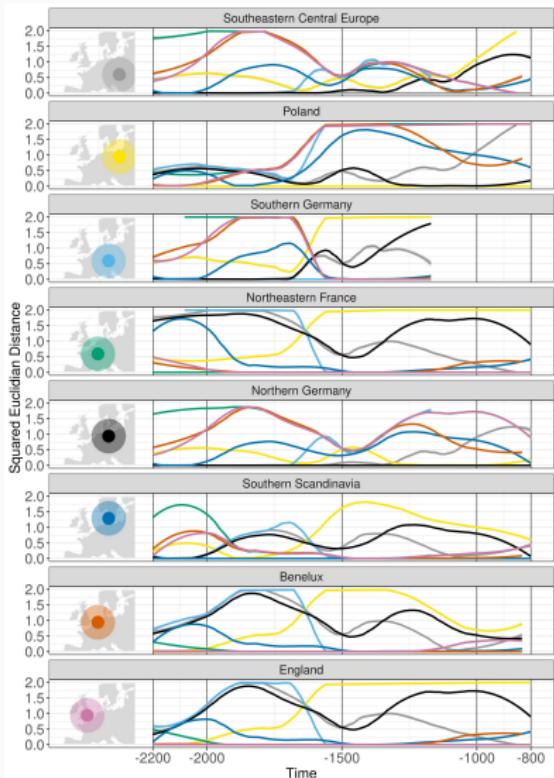
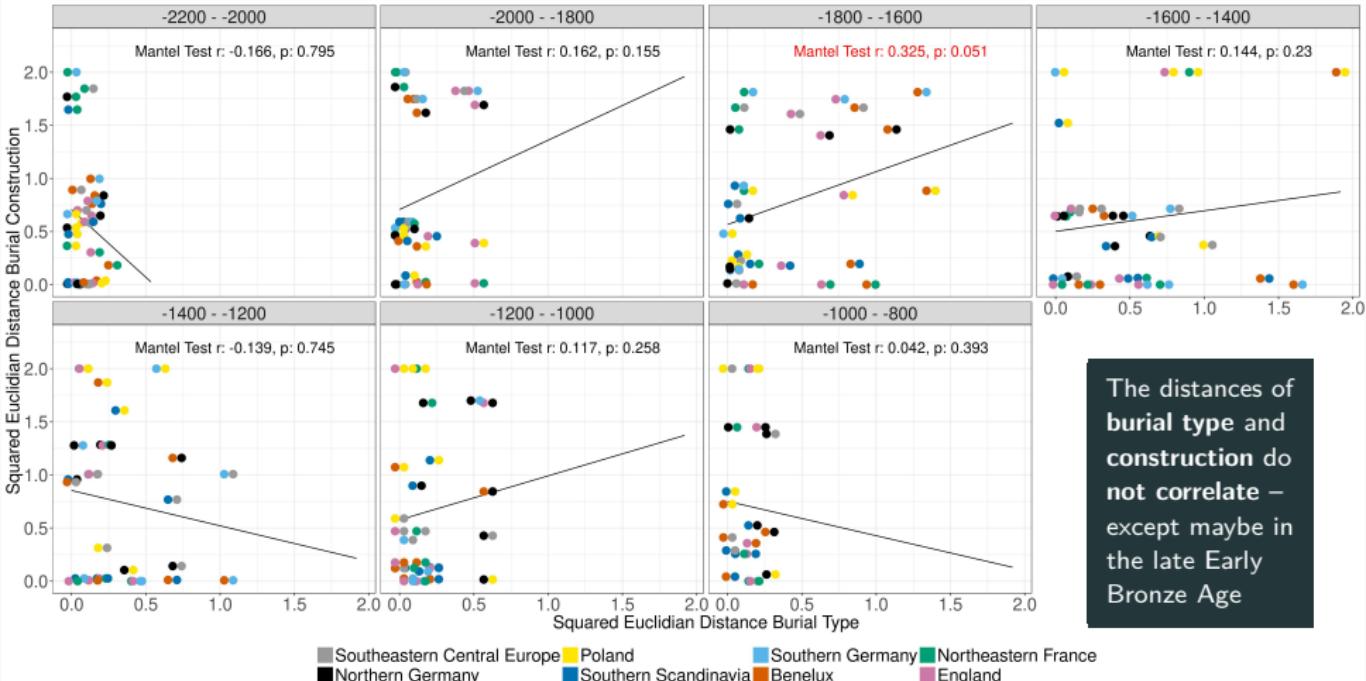


Figure 11: burial construction

Correlation of burial type and burial construction distance



**Figure 12: 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.

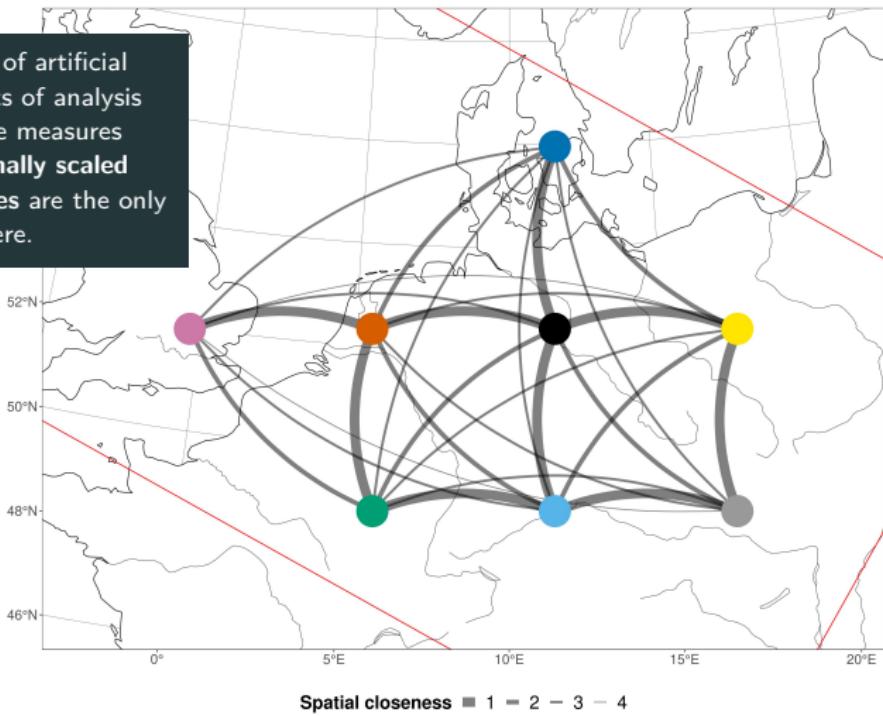


Figure 13: Spatial distance network and definition of distance classes

Correlation of burial type and spatial distance

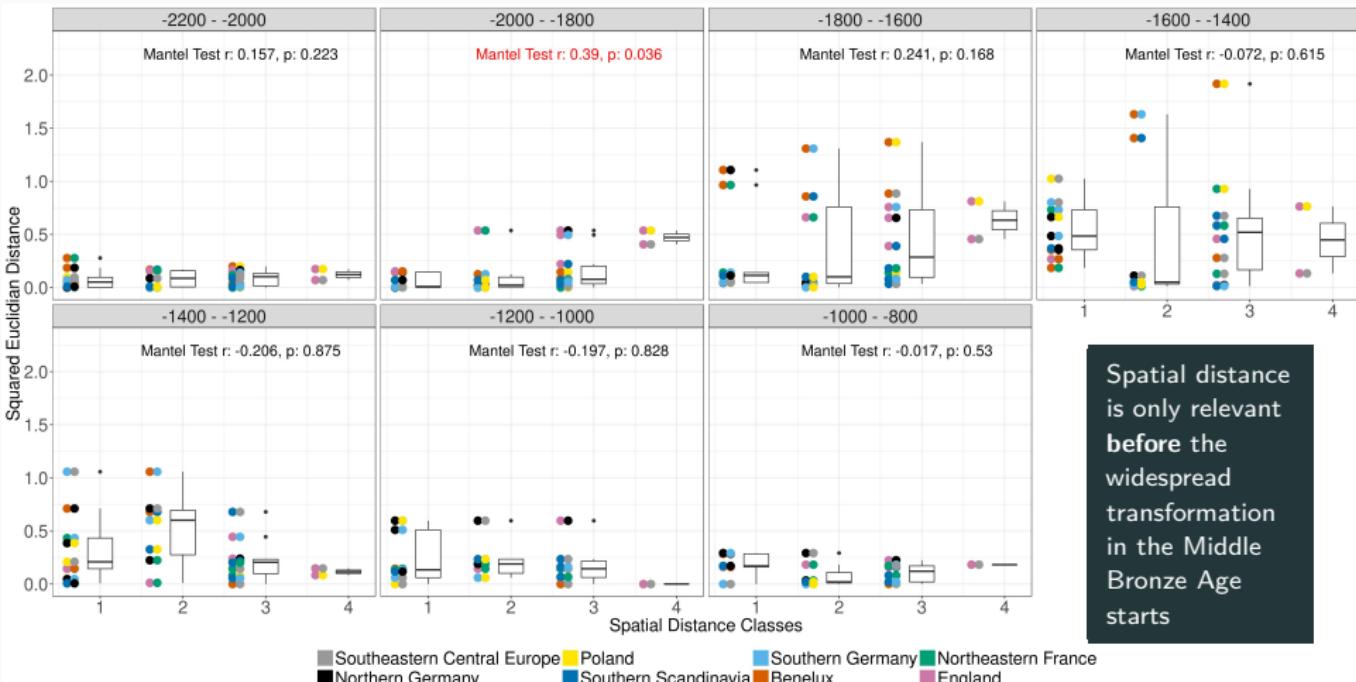
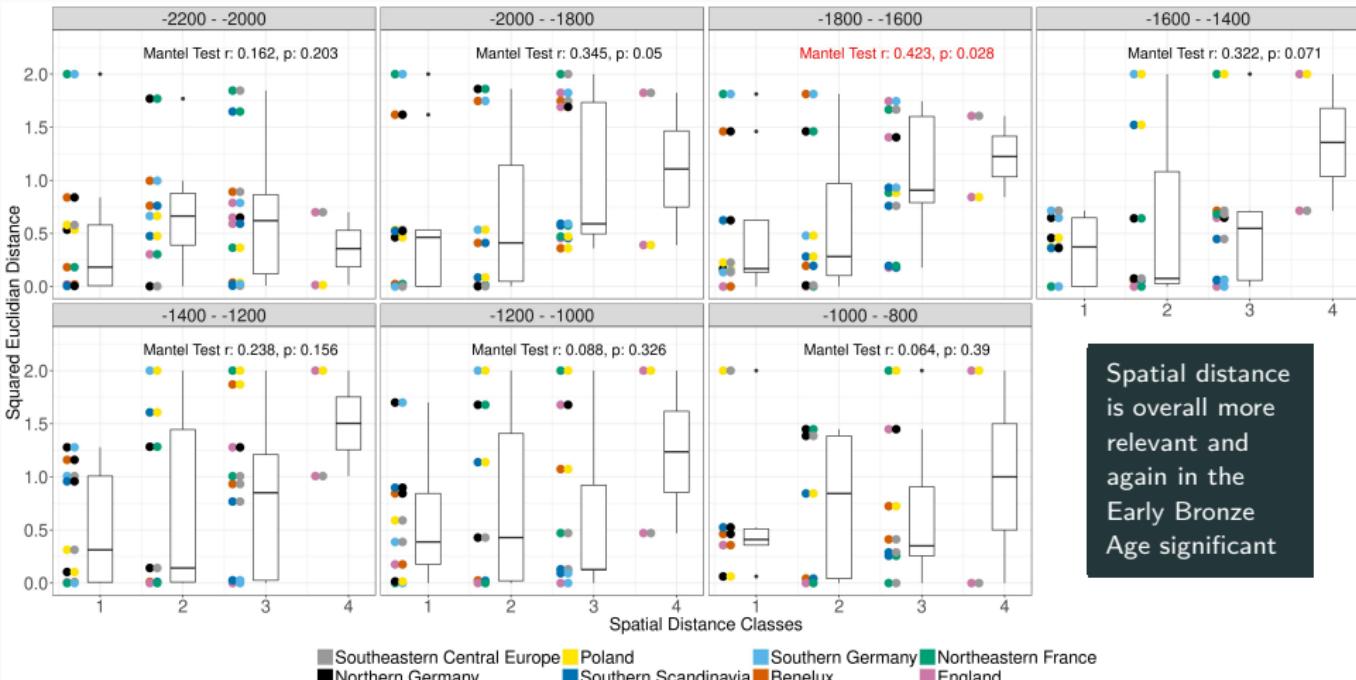


Figure 14: burial type: Correlation of mean SED and spatial distance in timeslices of 200 years.

Correlation of burial construction and spatial distance



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

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

Simulation

Concept

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

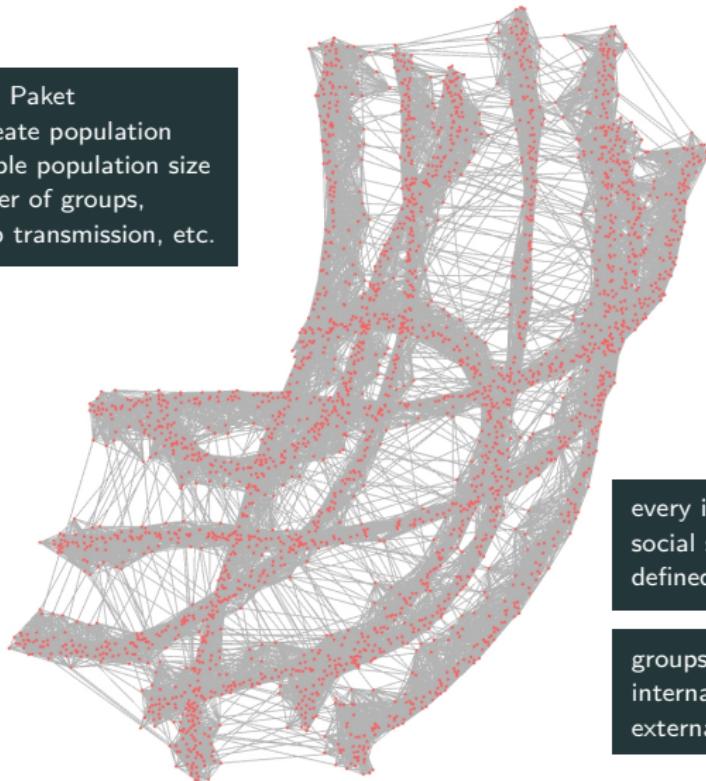
Drift: Dominanz of individual traits due to stochastic processes

Flow: Information transfer and synchronization across group boundaries

Concept: Ideas are **entities** that expand competitively in a **population graph**.

Population Graph

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



every individuals 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 16: Example Population Graph. Arranged with the Fruchterman & Reingold algorithm.

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( (double) std::get<2>(i) + 1) >= randunifrange(75, 100)
        );
    } else {
        success = std::make_pair(
            std::get<0>(i),
            std::get<1>(i) * log2( (double) std::get<2>(i) + 1) >= randunifrange(0, 100)
        );
    }
    success_per_neighbor.push_back(success);
}
...

```

Implementierung: 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?

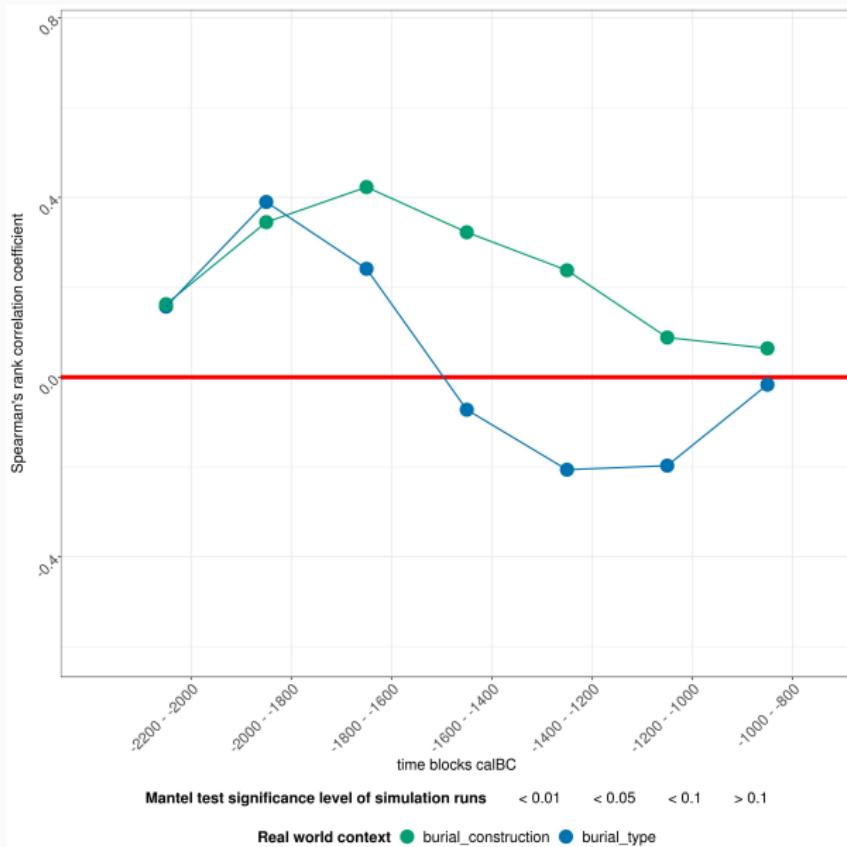


Figure 17: Correlation of cultural and spatial distance over time for **real world observations**.

Simulation Application: Correlation of Spatial and Cultural Distance

Is correlation
of spatial and
cultural
distance still
plausible?

Simulation
results in
comparison
with real world
data

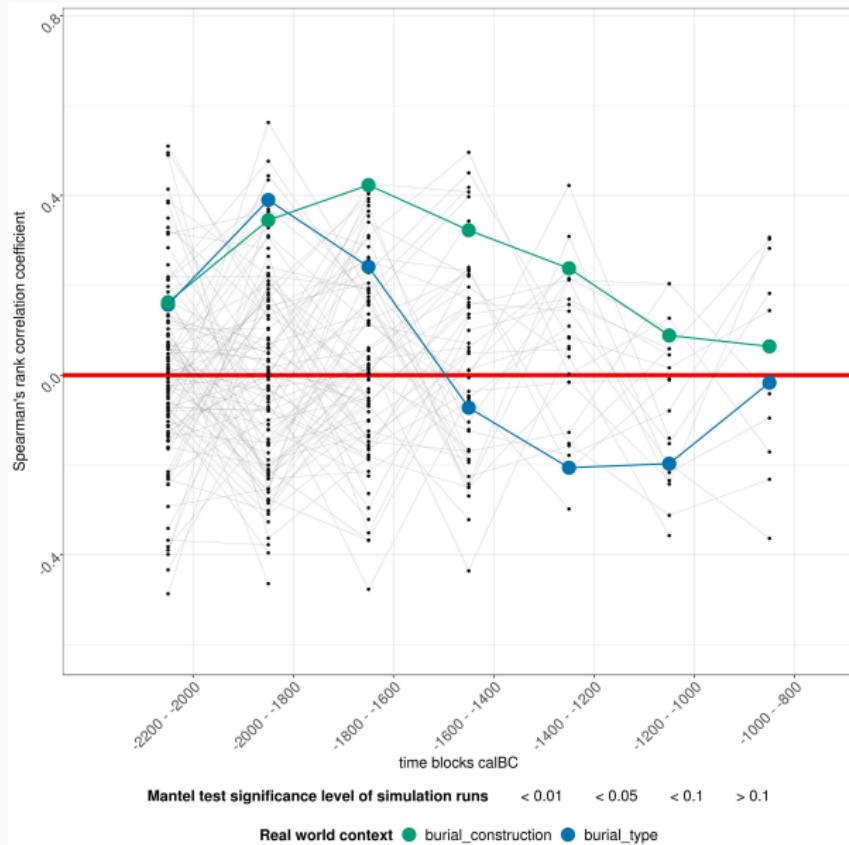


Figure 18: + Correlation development for 100 simulation runs with equal intergroup distance.

Simulation Application: Correlation of Spatial and Cultural Distance

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Simulation
results in
comparison
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data

The real world
correlation is
mostly within
the spectrum
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integroup
distance
simulations

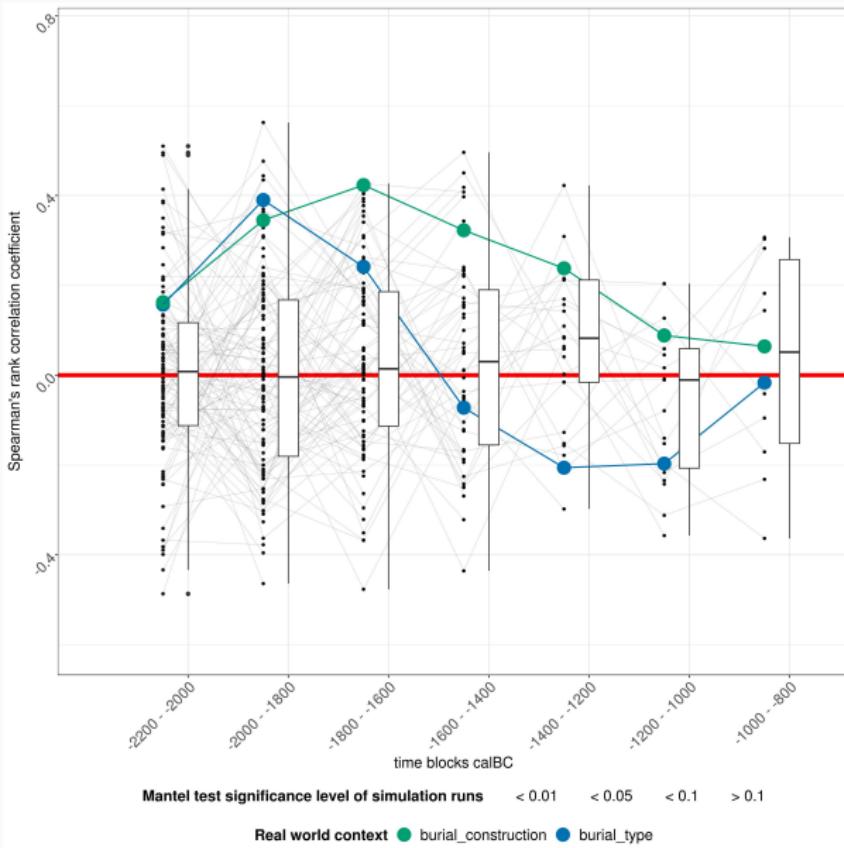


Figure 19: + Diagnostic boxplots for simulation runs.

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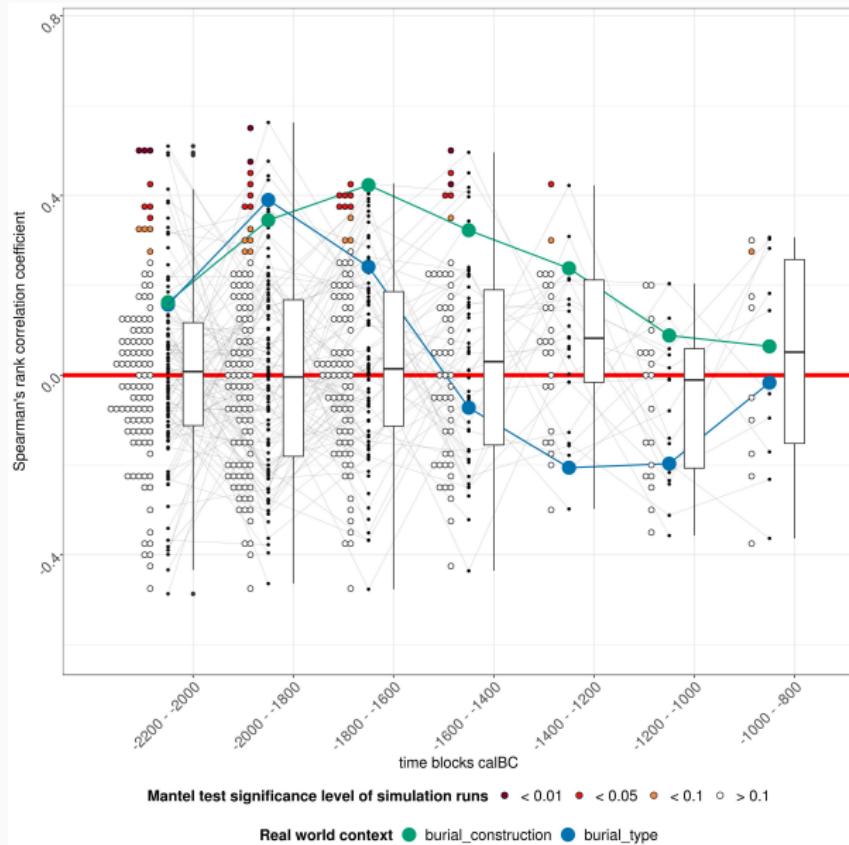


Figure 20: + Diagnostic dotplots indicating mantel test results.

Simulation Application: Correlation of Spatial and Cultural Distance

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Simulation
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Spatial
intergroup
distance in the
population
graph increases
correlation.

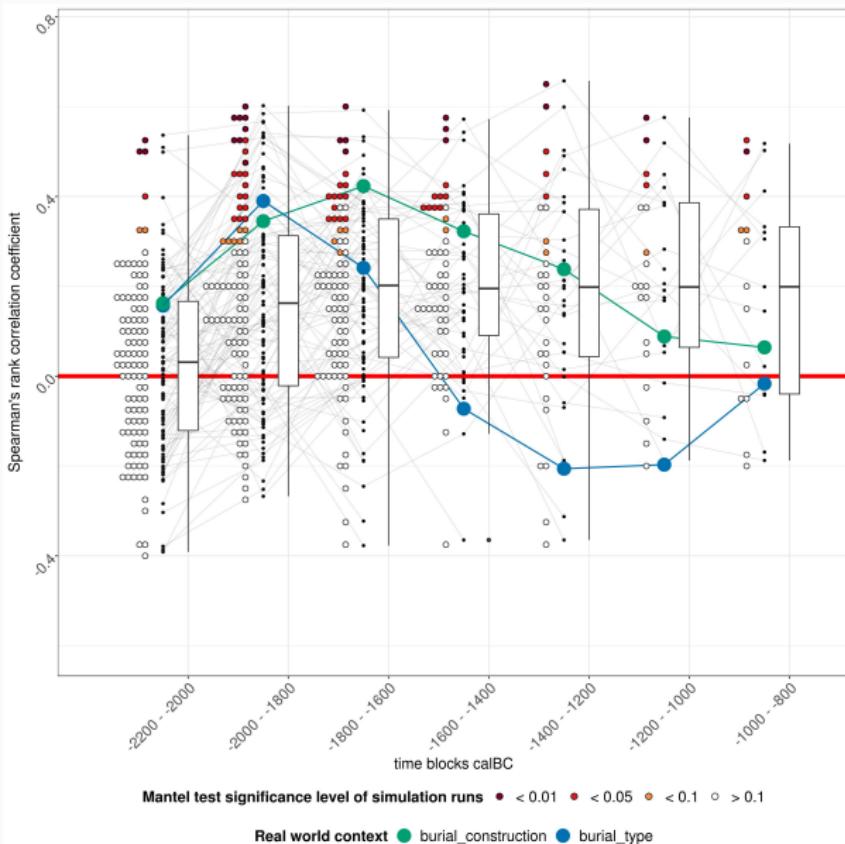


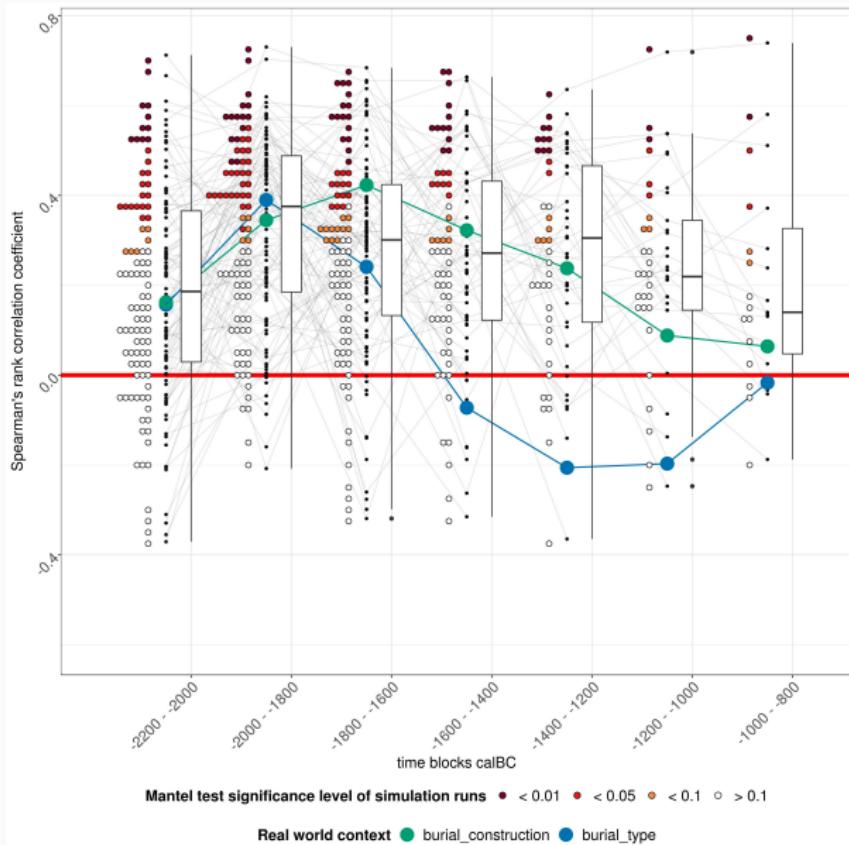
Figure 21: Same plot, but simulations now with low spatial intergroup distance.

Simulation Application: Correlation of Spatial and Cultural Distance

Is correlation of spatial and cultural distance still plausible?

Simulation results in comparison with real world data

The real world correlation is mostly within the spectrum 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 22: Same plot, but simulations now with high spatial intergroup distance.

Conclusion

Preliminary Observations and Hypotheses

- The diffusion of the cremation funeral tradition and traditions of flat vs. mound graves can both be explained by **neutral variant drift and flow** on a large scale. Local innovation might not have been necessary.
- Both contexts 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.
- The diffusion of cremation burials in the Middle and Late Bronze Age is **almost negatively correlated** with spatial distance.