

Quantitative analysis of cultural trait development

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

Clemens Schmid

@nevromeCS

github.com/nevrome
clemens@nevrome.de

github.com/
nevrome/
cultrans.
bronzeageburials.
uw2019

University of
Washington
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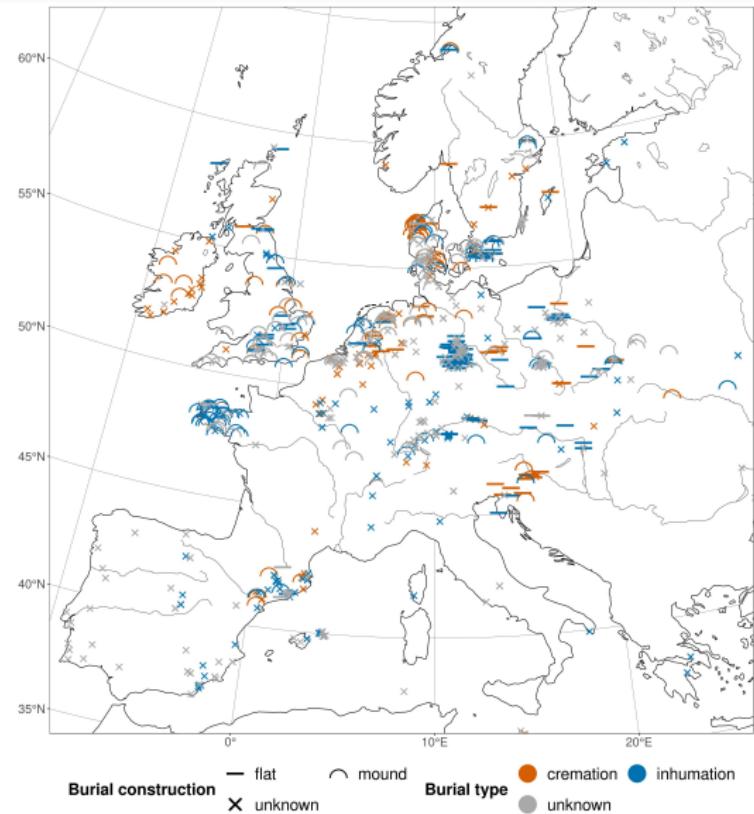
- Introduction to the data
- Cultural Distance
- Cultural and Spatial Distance
- Simulating Cultural Transmission

Introduction

Radiocarbon Dates on Graves

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).

Dates on Graves through Time

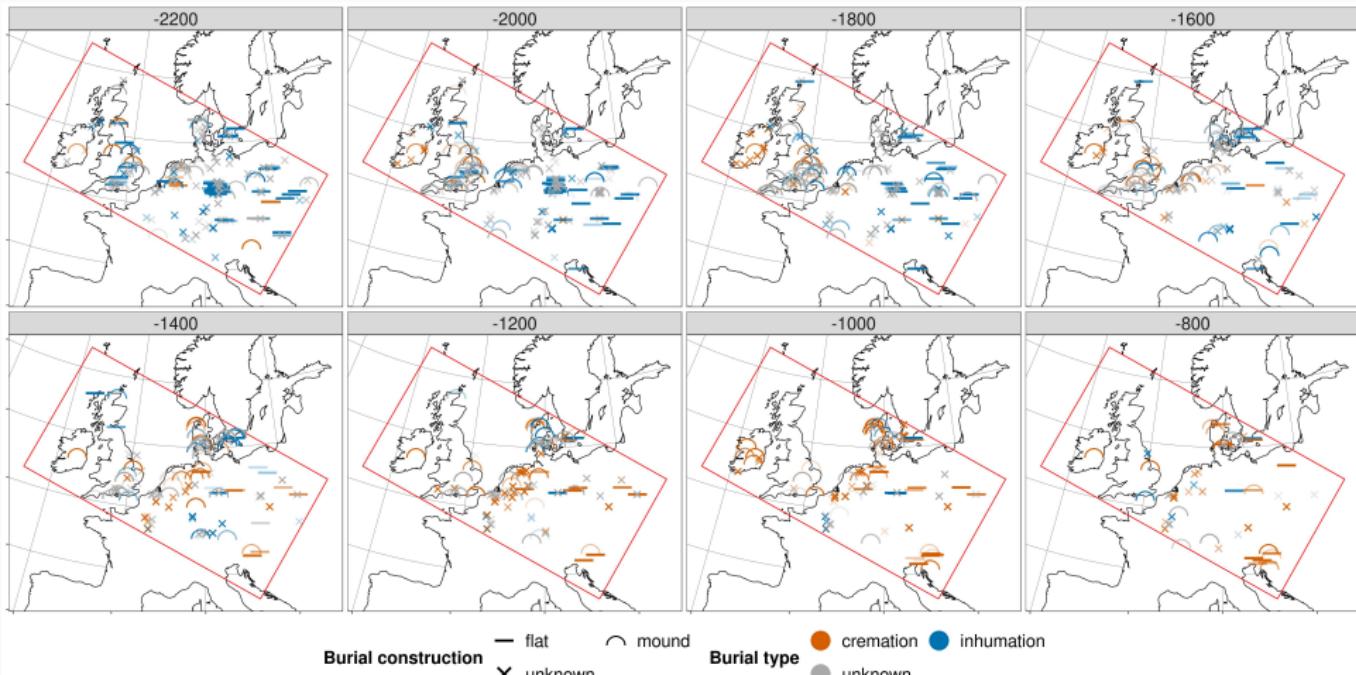


Figure 2: Plot matrix of radiocarbon dates on graves through time in the research area.

Artificial Macro-Regions

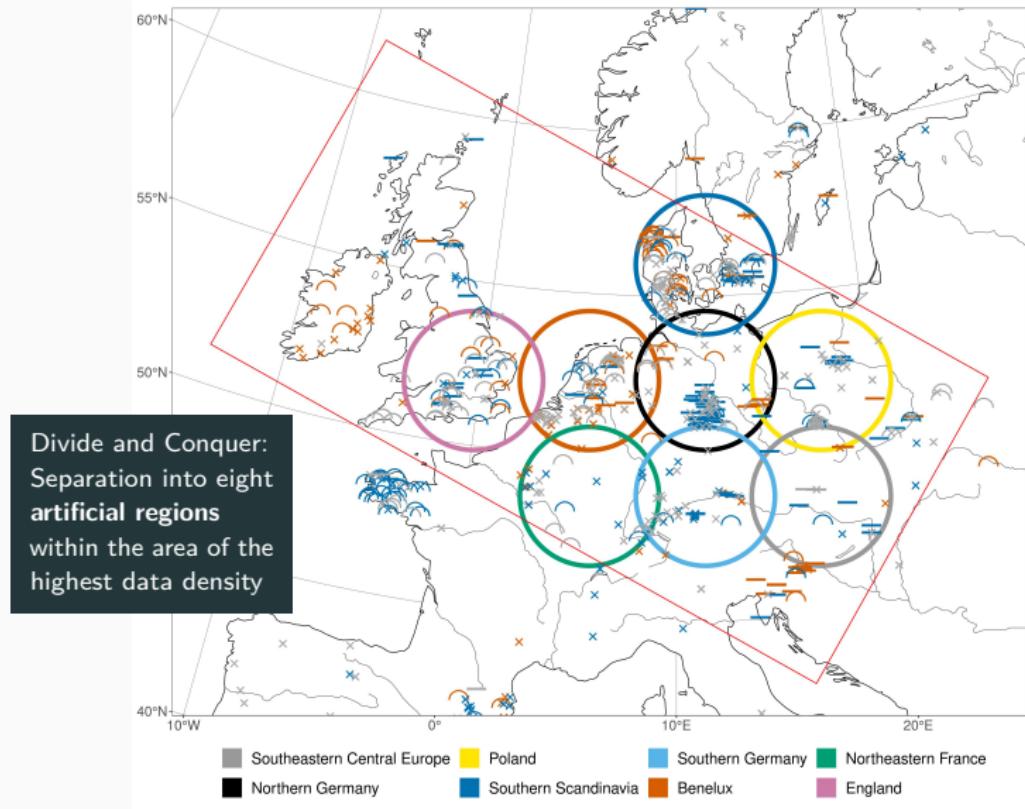


Figure 3: Artificial Regions: 400km distance, 240km radius, ≥ 70 dates.

Development – Absolute Numbers

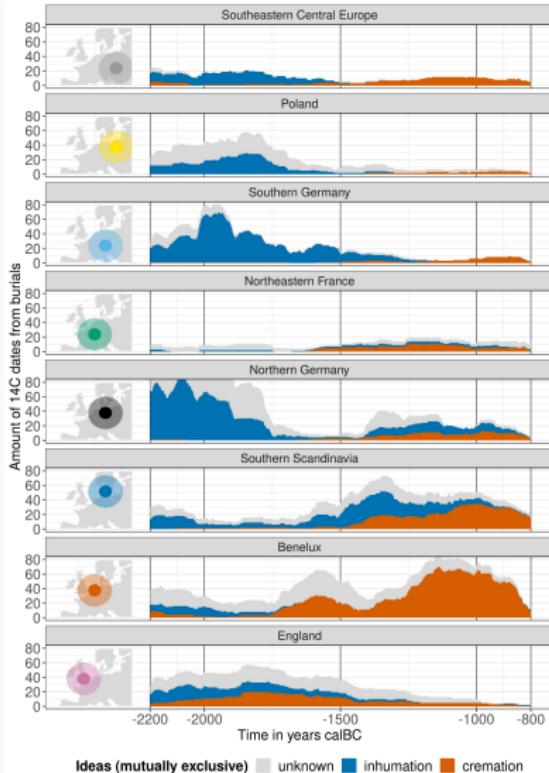


Figure 4: burial type development: Sum of ^{14}C dates whose 2σ range cover the respective year.

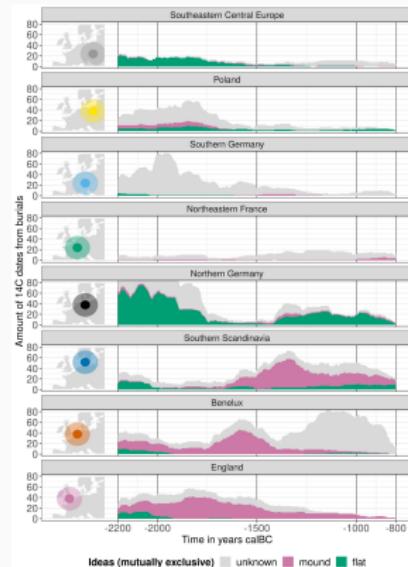


Figure 5: burial construction

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

Development – Proportions

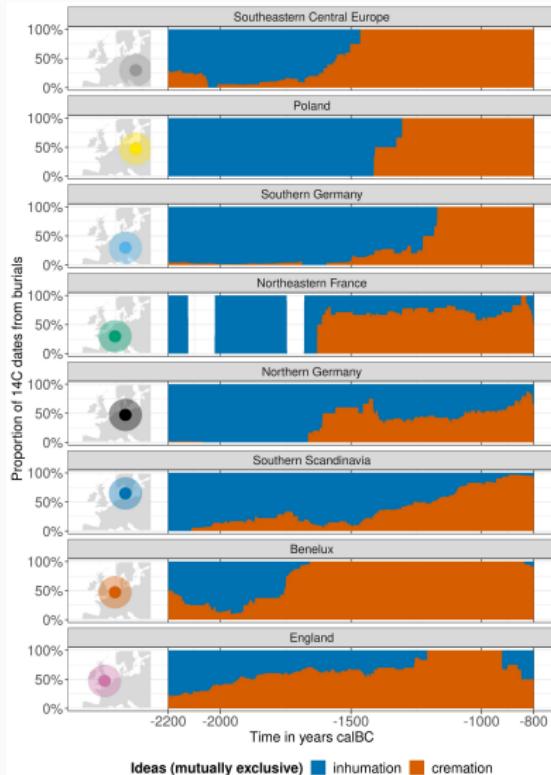


Figure 6: burial type development: Year wise proportions of dates. *unknown* is filtered out.

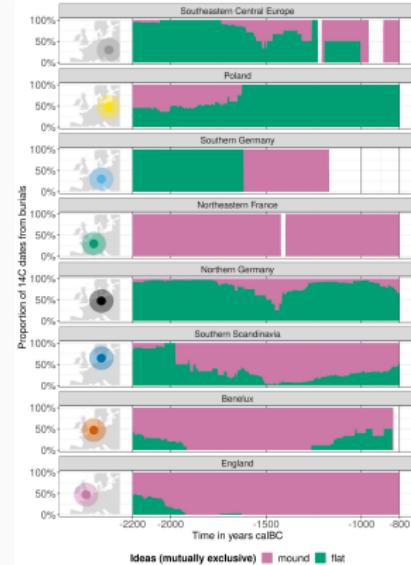


Figure 7: burial construction

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

Cultural Distance

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.

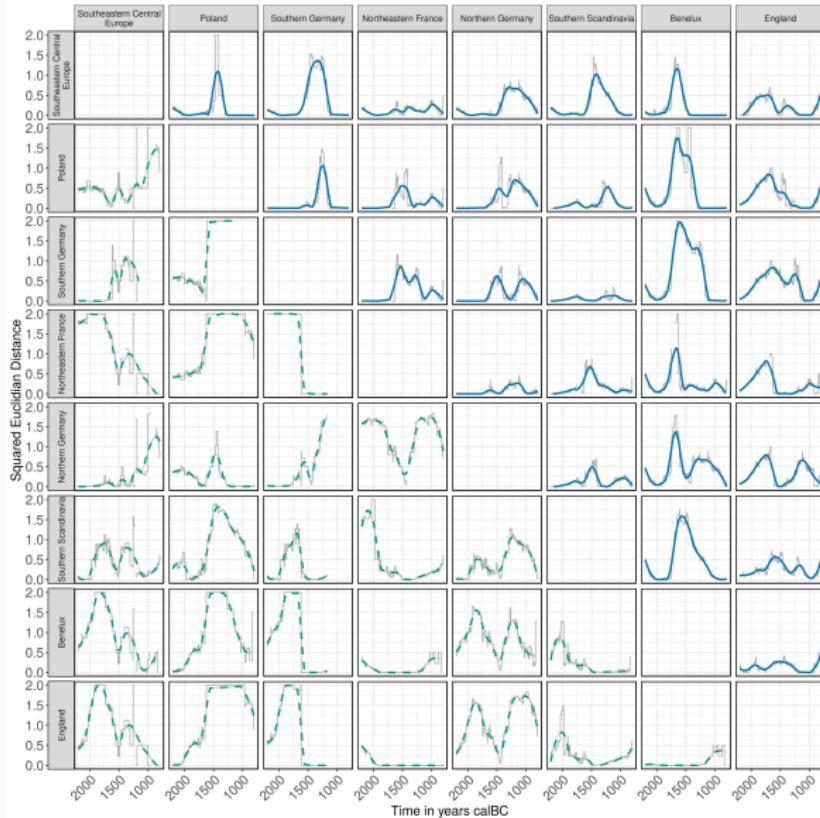
$$d_{ij}^2 = \sum_{k=1}^n (p_{ik} - p_{jk})^2$$

- 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

burial construction:
Heterogeneous distance development



burial type: 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 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?

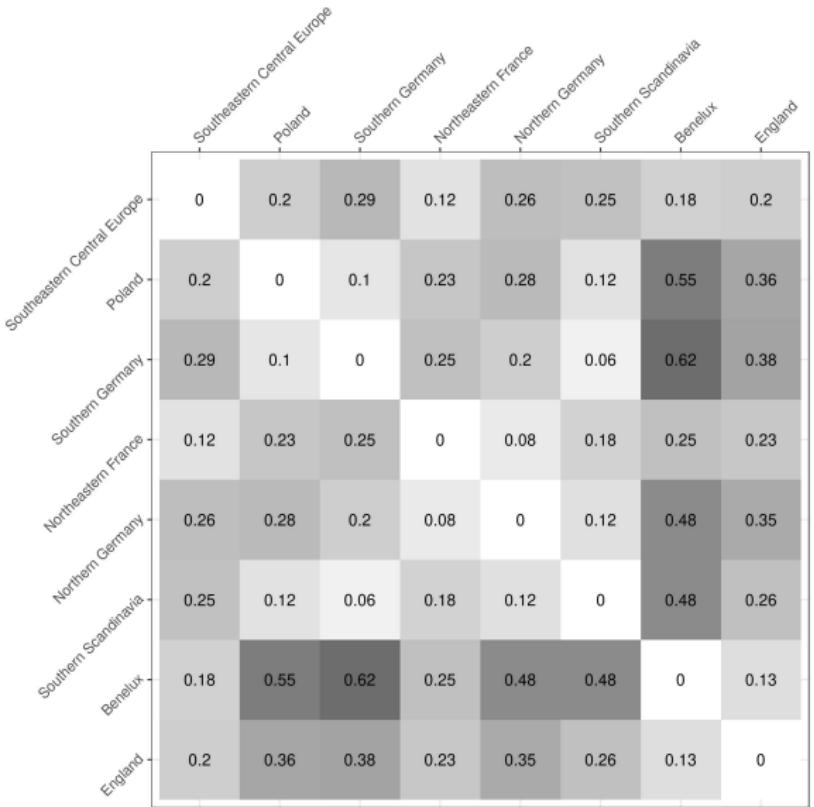


Figure 9: burial type: Mean SED for each region relationship. The lower, the closer.

Mean Region Distance Matrix

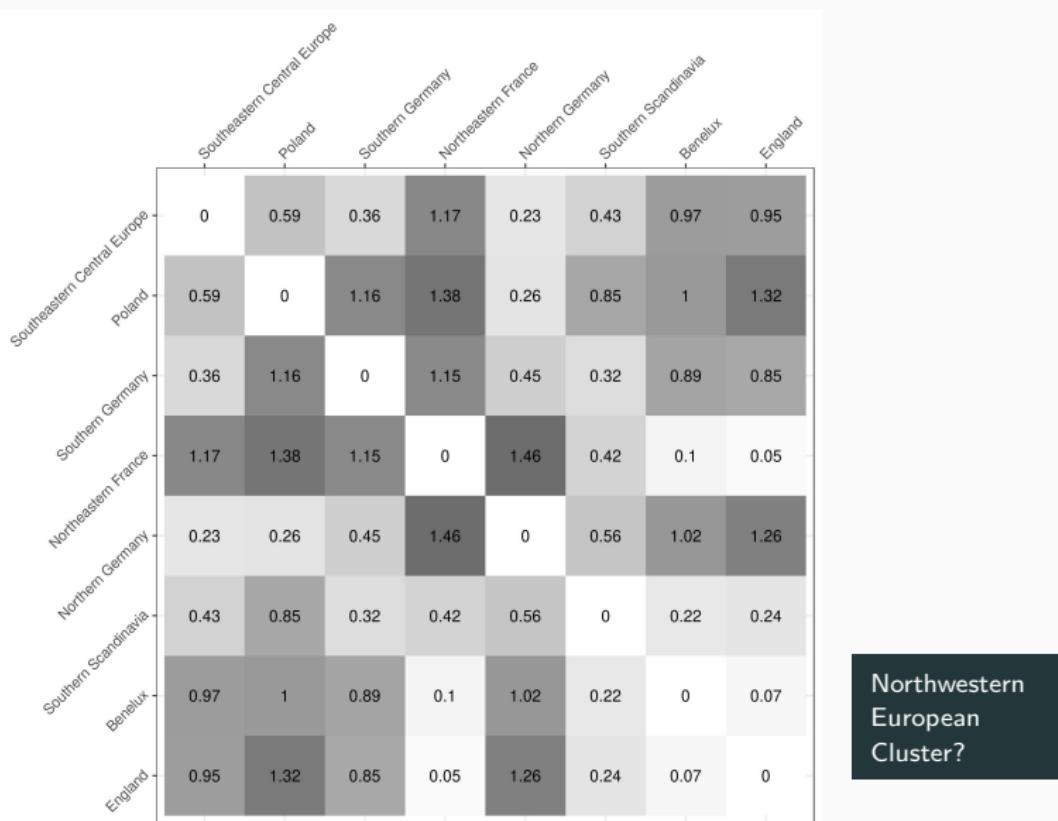


Figure 10: **burial construction:** Mean SED for each region relationship.

Parallel Developments of Burial Type and Burial Construction Distance?

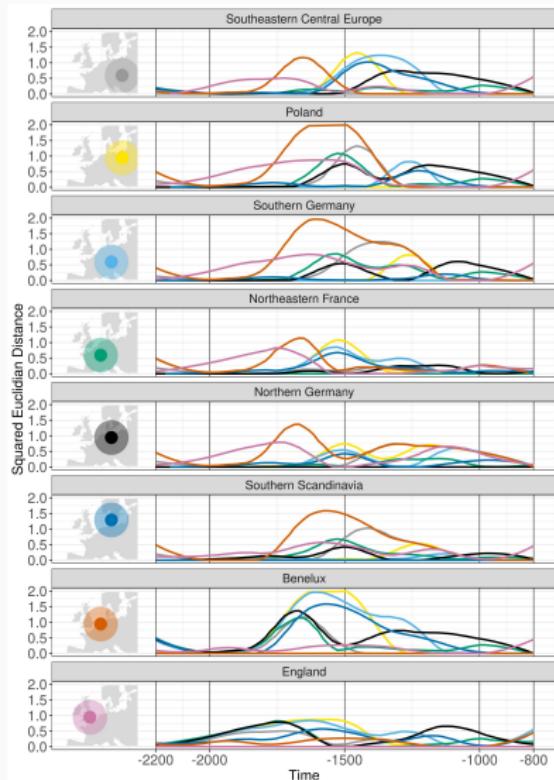


Figure 11: burial type Development of SED to all the others for each region.

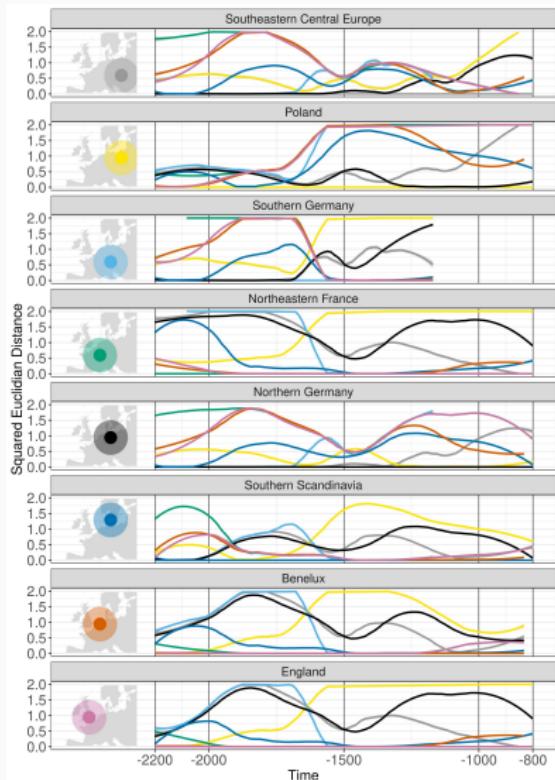
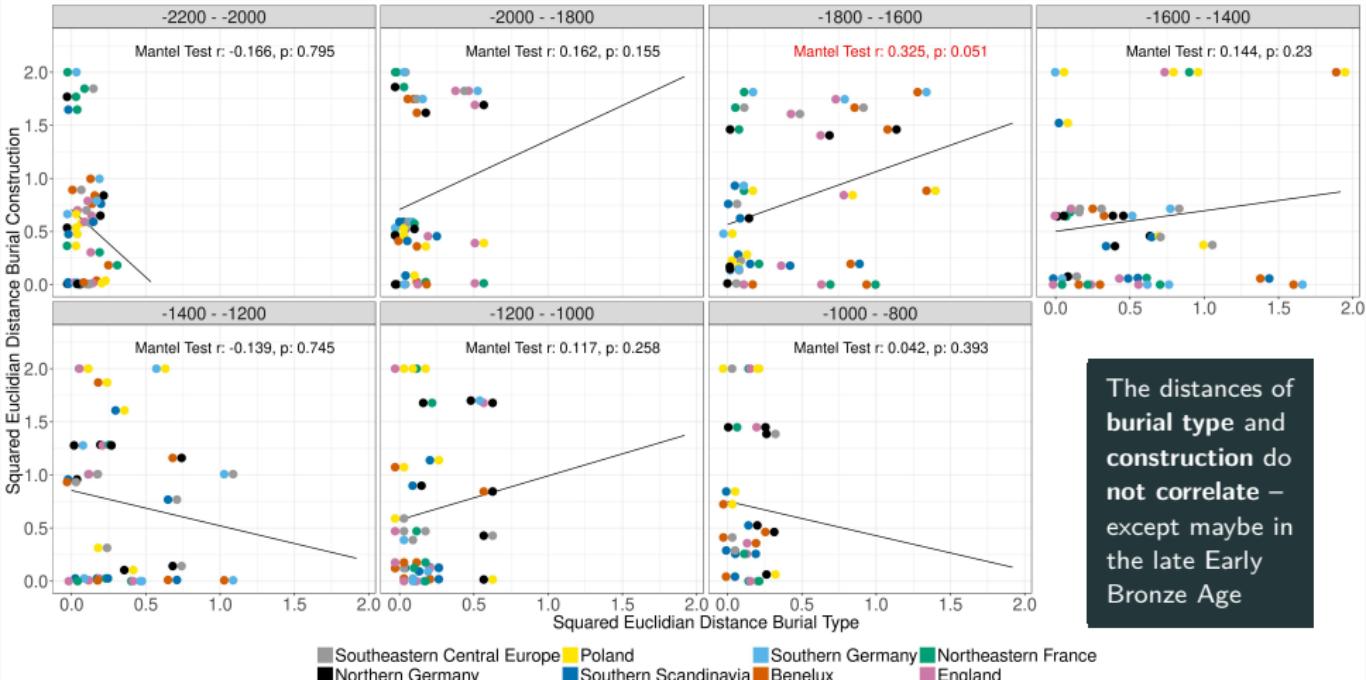


Figure 12: burial construction

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

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.

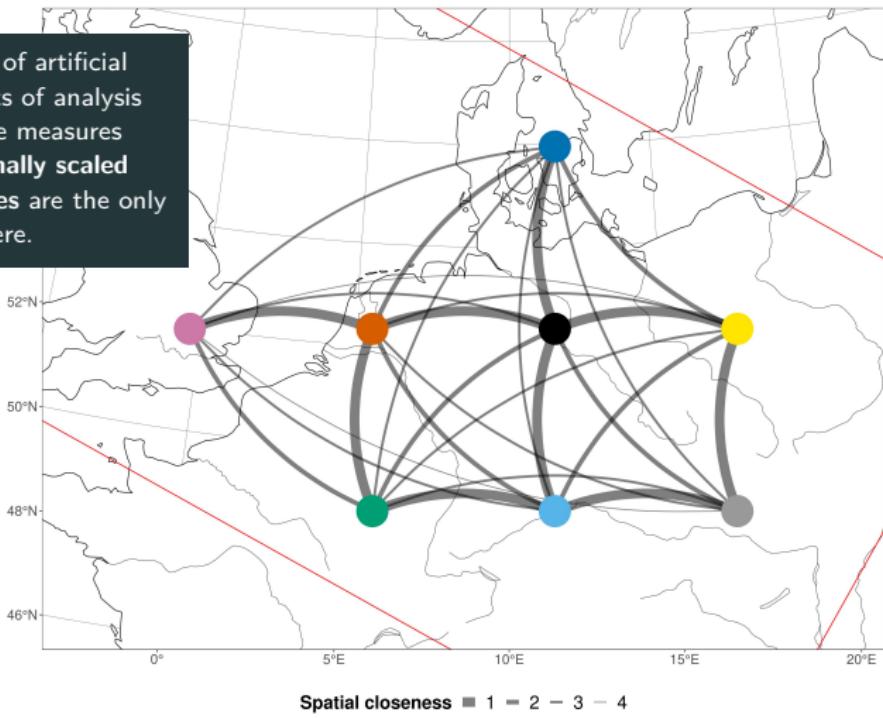


Figure 14: Spatial distance network and definition of distance classes

Correlation of Burial Type and Spatial Distance

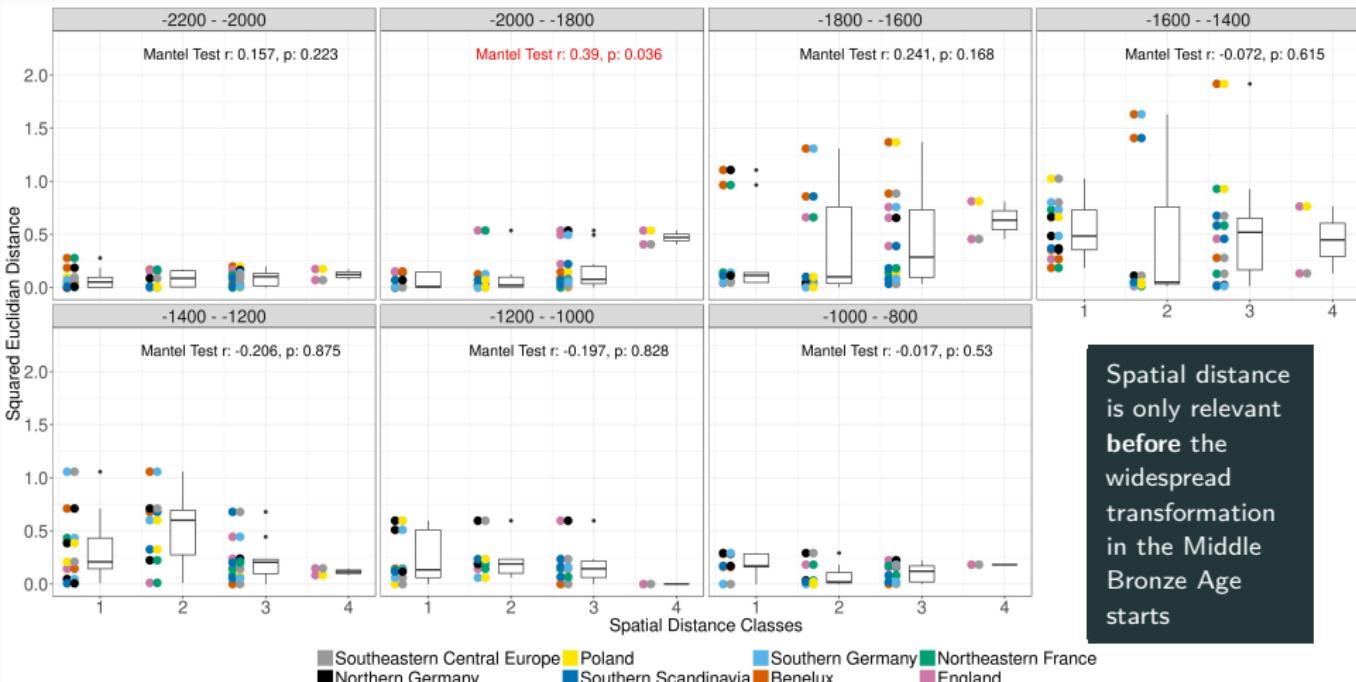
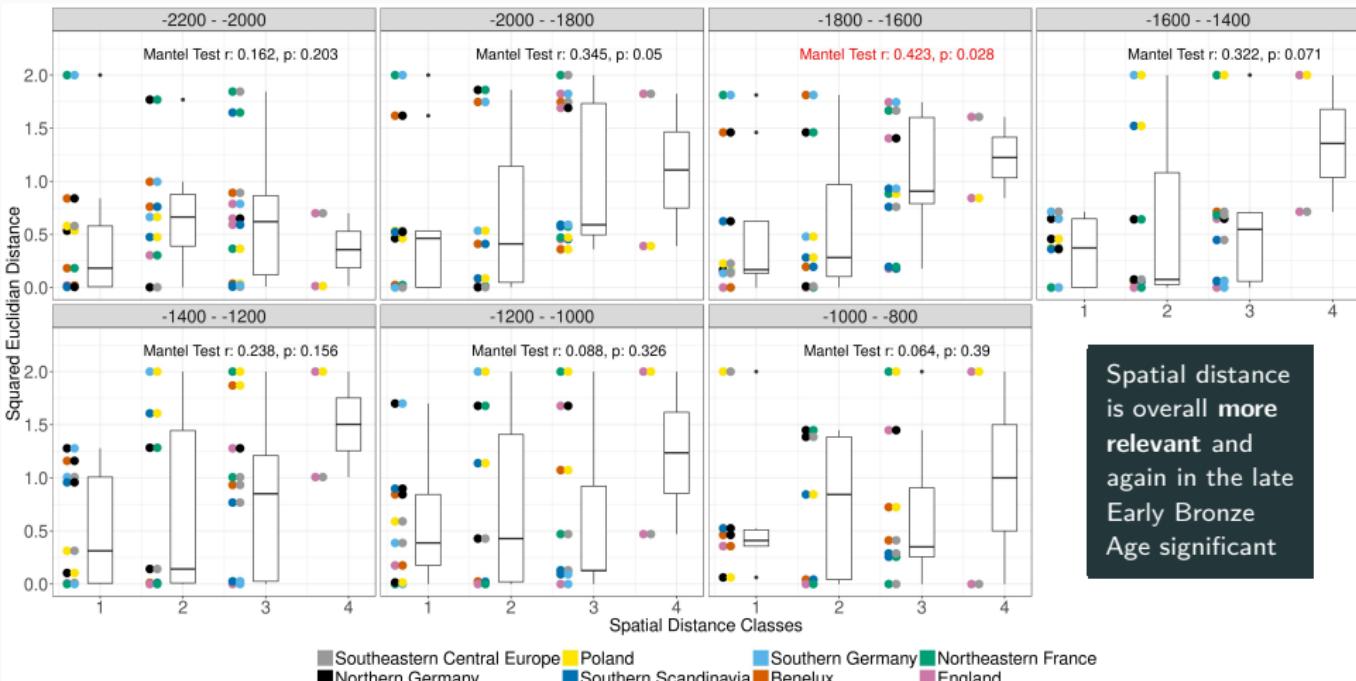


Figure 15: burial type: Correlation of mean SED and spatial distance in timeslices of 200 years.

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

Time series of Distance Correlation

A: Weak correlation in the EBA, negative correlation from the LBA

B: Slightly stronger correlation in the EBA, no correlation in the LBA

C&D: No significant correlation

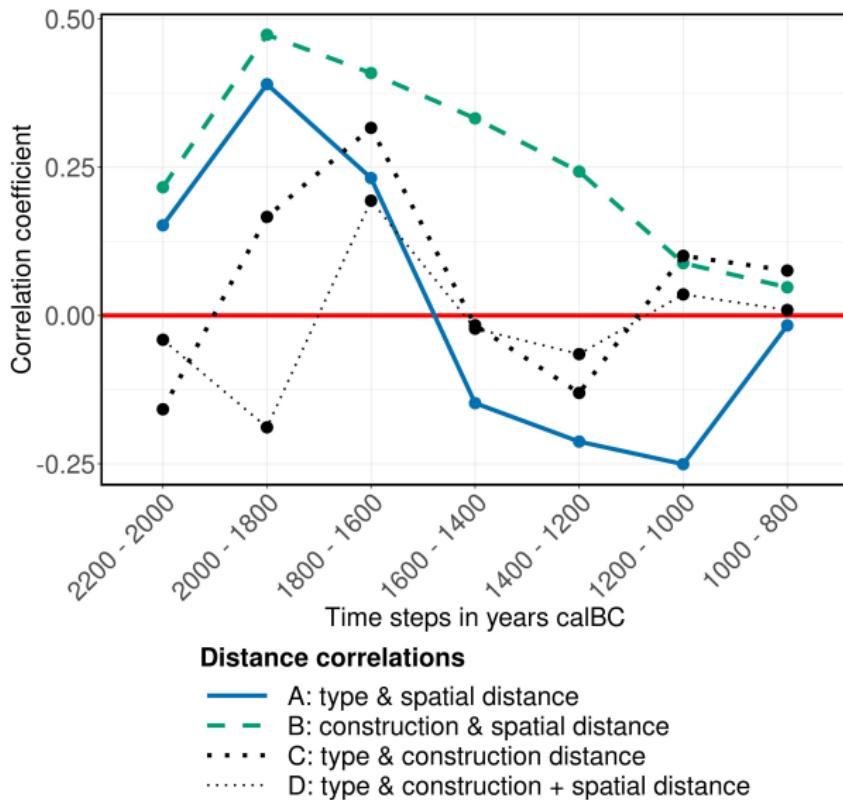


Figure 17: Time series of cultural and spatial distance correlation.

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*.

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.

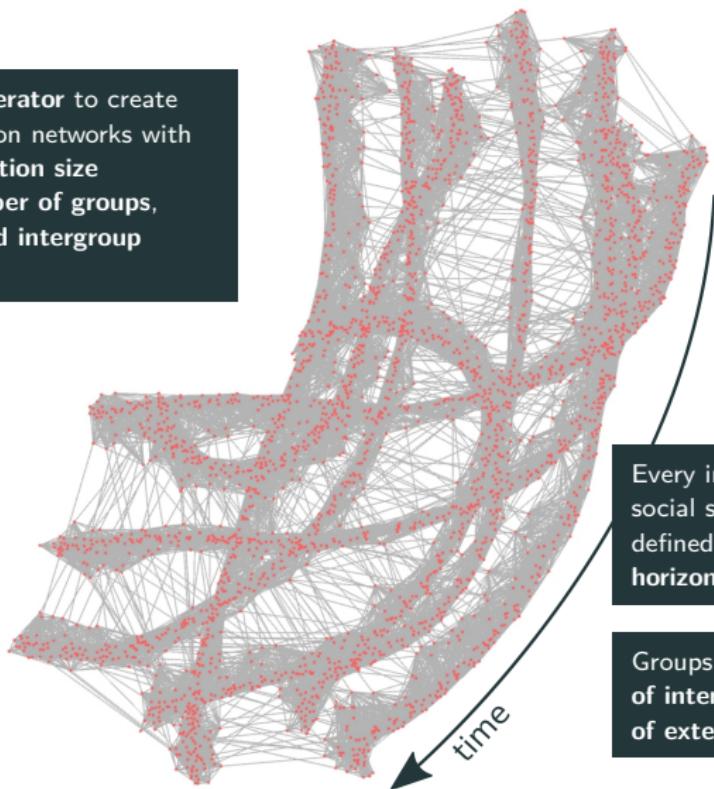


Figure 18: Example Population Graph. Arranged with the Fruchterman & Reingold algorithm.

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?

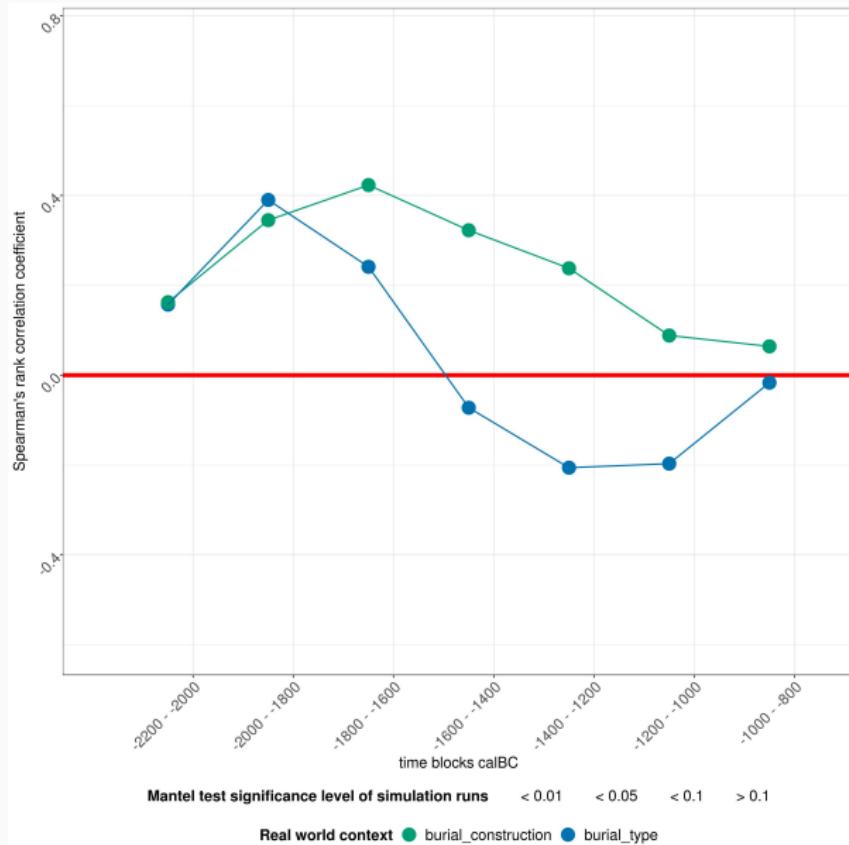


Figure 19: Correlation of cultural and spatial distance over time for **real world observations**.

Simulation Application: Correlation of Spatial and Cultural Distance

Can
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spatial and
cultural
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ruled out?

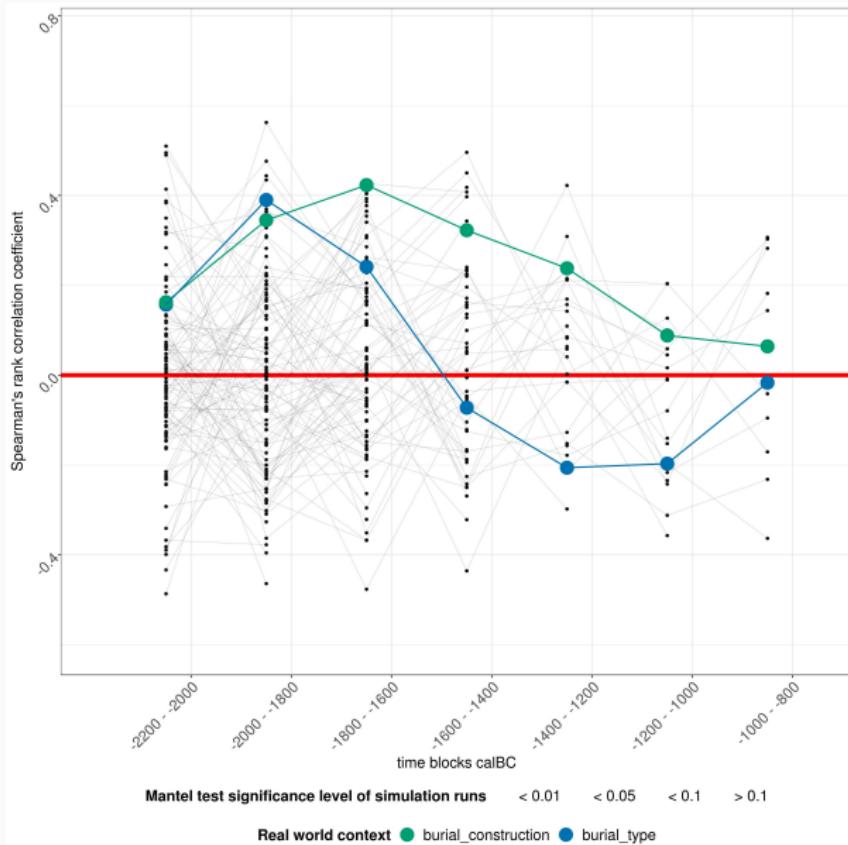


Figure 20: + Correlation development for 100 simulation runs with equal intergroup distance.

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

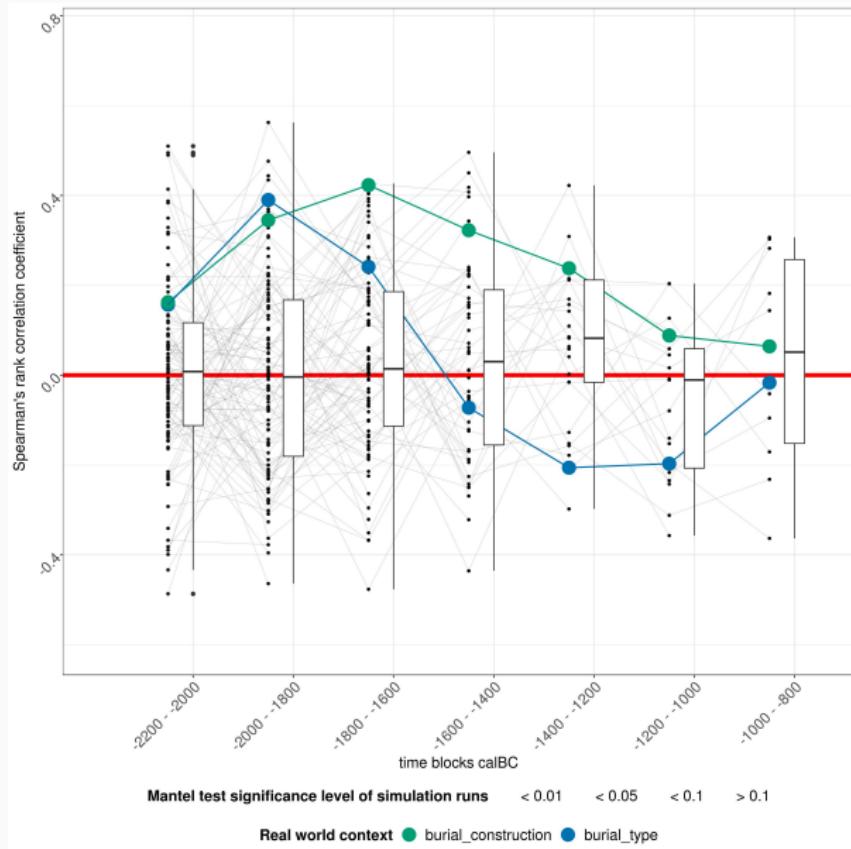


Figure 21: + Diagnostic boxplots for simulation runs.

Simulation Application: Correlation of Spatial and Cultural Distance

Can
correlation of
spatial and
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Equal
intergroup
distance:
Unlikely
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Bronze Age

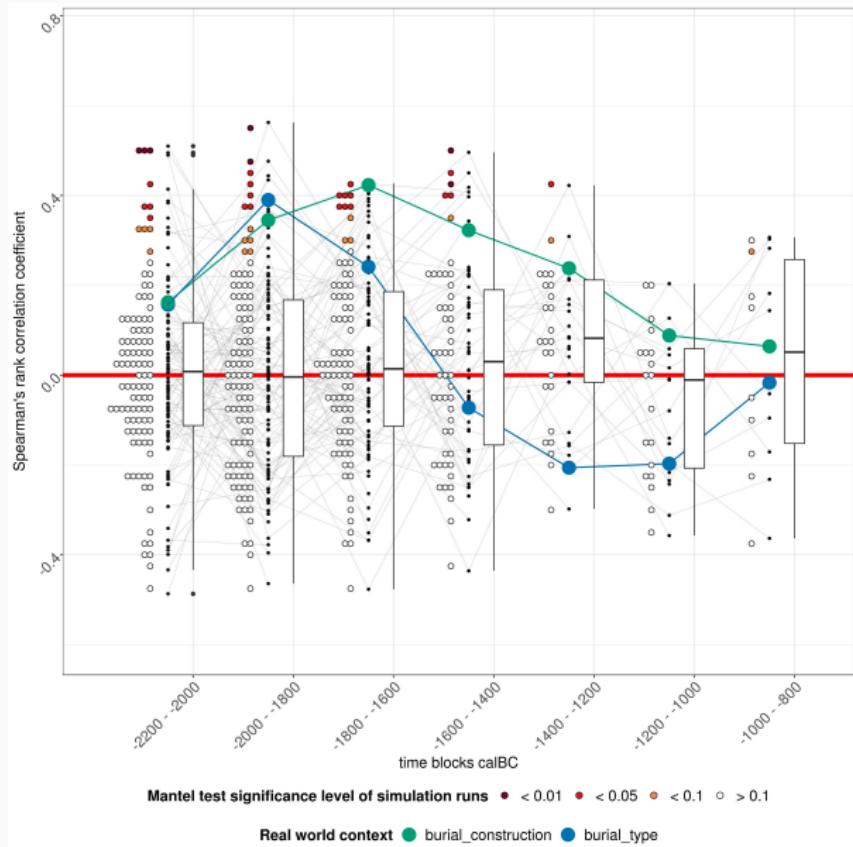


Figure 22: + Diagnostic dotplots indicating mantel test results.

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

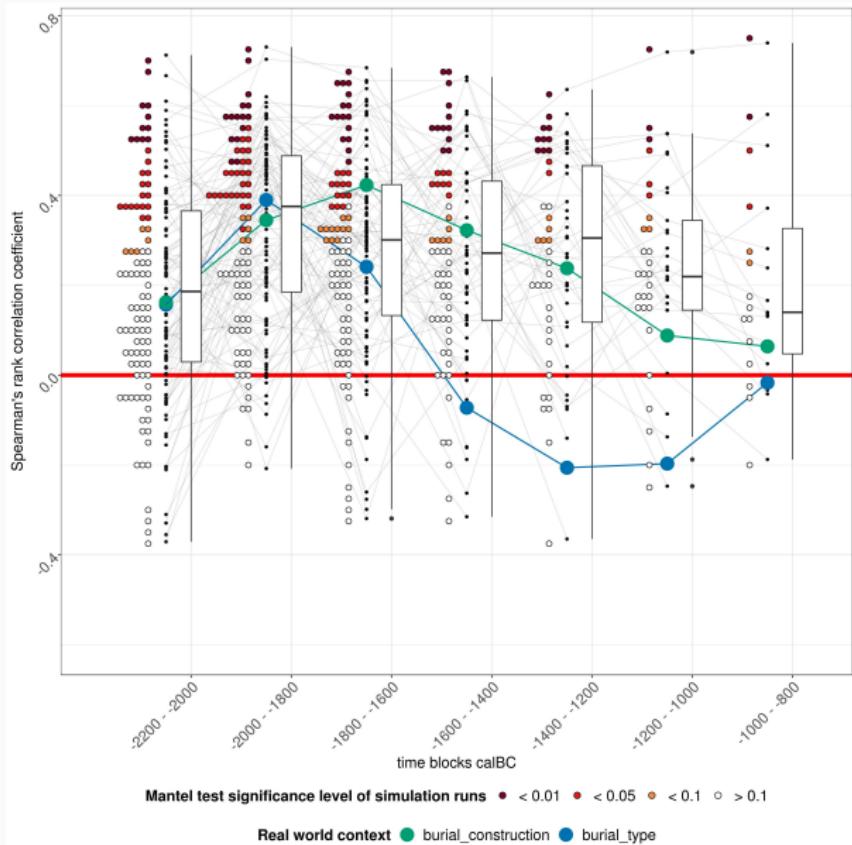


Figure 23: Same plot, but simulations now with **spatial intergroup distance**.

Conclusion

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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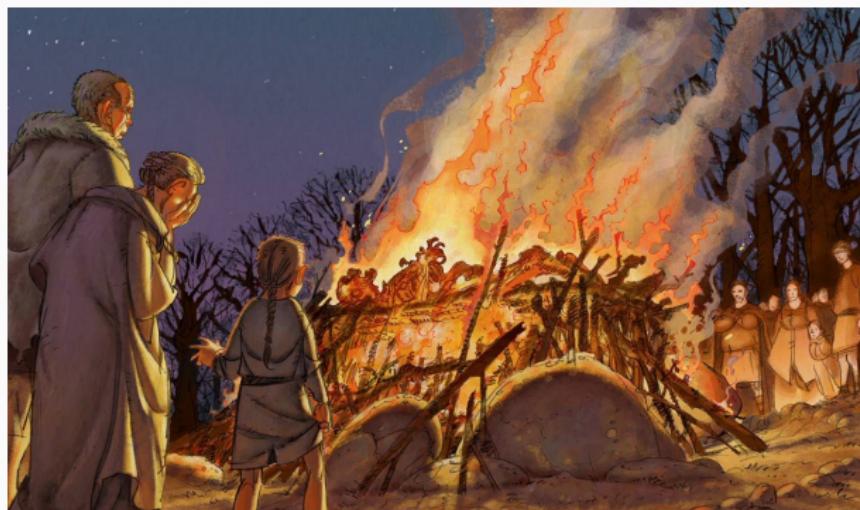
Clemens Schmid

@nevromeCS

github.com/nevrome
clemens@nevrome.de

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