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MEETING REPORT

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Empirical evaluation of encoding multi-temporal quantitative data using spatial unit sizes

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ABSTRACT

The concept for visually encoding multi-temporal quantitative data, which is based on adjusting sizes of spatial units according to change values, is briefly introduced and empirically tested. This concept (called 'Sponge Maps') includes three optional extensions of the underlying Value-by-area Map concept – considering the total map size, different scaling function, and dual coding. All in all, the empirical study confirmed the expected intuitiveness and effectiveness of the concept. The detection rates (roughly between 60% and 80%) are lower compared to conventional choropleth maps using colour lightness encoding. It is assumed that this is due to the unfamiliarity of the new concept and missing explanations for test users. Since the choice of design parameters is made by the map author, there is also a certain degree of subjectivity in the creation of Sponge Maps – therefore, corresponding countermeasures are sketched out.

RÉSUMÉ

Le concept d'encodage visuel de données quantitatives multi-temporelles, qui est basé sur l'ajustement de la taille des unités spatiales en fonction de variations de valeur, est brièvement présenté et testé de façon empirique. Ce concept (appelé les cartes éponges) comprend trois extensions en option du concept sous-jacent de cartogramme - la prise en compte de la surface totale, une fonction de mise à l'échelle, ou une représentation double. Dans l'ensemble l'étude empirique a confirmé l'intuitivité et l'efficacité du concept. Le taux de détection (environ entre 60 et 80%) est plus faible de celui des cartes choroplèthes traditionnelles utilisant la luminosité de la couleur pour représenter les variations. On fait l'hypothèse que cela vient du fait que ce nouveau concept est peu connu et que les utilisateurs testeurs n'ont pas reçu d'explications à son sujet. Dans la mesure où le choix des paramètres de conception est effectué par l'auteur de la carte, la création des cartes éponges comporte également un certain degré de subjectivité, c'est pourquoi des contre-mesures correspondantes sont esquissées.

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1. Introduction

Goal of this paper is to empirically evaluate an alternative concept for encoding multi-temporal quantitative data, which is based on adjusting sizes of spatial units (typically, enumeration units) according to change values.

The **relevance** of this topic arises, on the one hand, from the increasing demand for multi-temporal analyses in disciplines such as epidemiology, climate and environmental change, disaster management or mobility. On the other hand, more and more multi-temporal data is generated by satellite-, drone- or terrestrial-based sensors, sensor networks or GNSS in smartphones (Salcedo-Sanz et al., 2020). Consequently, there is also a need for more advanced analytical methods, including multi-temporal visualizations for presentation and exploration purposes.

The most common layout approaches for visualizing multi-temporal, quantitative data are either small multiples (i.e. a side-by-side presentation of static maps of different points of time) or cartographic animations (i.e. a temporal sequence of those maps). The problem is that both layouts – in combination with conventional encoding approaches such as colour lightness – have disadvantages in terms of usability due to limited space or viewing time (see Sect. 2 on previous work).

In an earlier publication (Schiewe, 2025; accepted), an alternative encoding **approach** for change values has been proposed, the adjustment of the size of spatial units (typically, enumeration units) according to change values. In analogy to proportional symbol (sign) maps, for example, doubling the area size of an enumeration unit between two periods corresponds to double value size. This principle is well known from Value-by-area Maps (Dorling et al., 2006), which are typically used for mono-temporal maps only. This principle is now transferred to multi-temporal maps and extended by three design options:

- There are two variants of the resulting total map size – either this is changed according to the overall change of all units (Total Change Maps), or the size is kept constant for the entire time series, which requires the normalization of total sizes of each period (Normalized Change Maps).
- The relationship between change in value and change in graphical size can be defined in a different manner, not only as proportional scaling, but also using other scaling functions that can enhance the visual appearance of changes or avoid too strong distortions. Due to this adjustable property, the term 'Sponge Maps' is also used for this concept.
- The reference units of the Sponge Maps can additionally be colour-coded; for example, to depict the original absolute values of the respective regions (dual coding).

More details on the approach are given in Sect. 3.

In this contribution the **research question** will be investigated whether users intuitively understand the new encoding approach of varying spatial unit sizes (in static, bi-temporal maps) and apply it effectively. For this purpose, the aforementioned three design options have been tested in detail in a web-based study with 101 participants (Wolf, 2024), which will be treated in Sect. 4.

Since the choice of the aforementioned design parameters is made by the map author, there is also a certain degree of subjectivity in the creation of Sponge Maps. Therefore, appropriate measures to create transparency are also shown (Sect. 5). Finally, Sect. 6 will summarize results and outline future work.

2. Previous work

2.1 Justification of the approach

The idea of testing an alternative encoding method for multi-temporal data is derived from the problems of conventional encodings in combination with conventional layout methods.

With respect to **layouts**, the basic problem with map series is the space required or the limited space available. This problem can be overcome by using small multiples (DiBiase et al., 1992; Slocum et al., 2009); however, this can lead to readability problems. The obligatory eye movements from map to map (saccades) have a negative effect on the perception of information (Goldstein, 2002). If there is a relatively large amount of space available, the maps can be made larger, but the saccades become even wider as a result.

Cartographic animations have the advantage over the map series that the temporal sequence is made explicit - accordingly, added value has also been demonstrated in the communication of spatio-temporal trends (Harrower & Fabrikant, 2008), processes and patterns (Lan et al., 2021), or clusters (Griffin et al., 2006). However, the key disadvantage of animations is the limited viewing time of the individual periods (especially with continuous animations), which is very often not sufficient for a complete or necessary recognition of encoded information (Harrower, 2007; Rensink, 2002). The second disadvantage is that – in contrast to the map series – only states between two consecutive points in time can be directly compared, while larger time differences are hardly to perceive. Animations should therefore ideally be used for depicting uniform spatiotemporal trends. The integration of interactive control elements can of course provide a remedy, but especially in comparison to the map series, their use represents an increased effort on the part of the user, which ties up further cognitive resources.

Both small multiples and animations can also experience the 'area-size bias', describing the neglect of small areas, since these are less dominant in perception than larger ones (Schiewe, 2019).

Focusing on the **encoding** of changes only, the graphic variables size, lightness or saturation are typically used for this purpose. The use of colour lightness or saturation for multi-temporal and mainly animated choropleth maps is investigated, for example, by Fish et al. (2011), Moon et al. (2014) or Traun et al. (2021). While the colouring supports the visual detection of patterns, it also requires the mental efforts to 'translate' the change in lightness into change in value (applying the so-called 'dark-is-more bias'; Schloss et al., 2019). It can be argued that this additional mental load hinders a fast recognition of changes, in particular, in map animations.

Another encoding variant is the use of size in point symbol (sign) maps (Kostelnick et al., 2007). However, it is not suitable for displaying relative (normalized) areal data and for visually detecting spatio-temporal patterns.

Finally, dual coding using the graphic variables size and lightness (saturation) is possible, but its success is controversially discussed: Kronenfeld & Yoo (2023) found no added value of symbol sizes compared to colour in choropleth maps, whereas Cybulski and Medyńska-Gulij (2018) recognized an improved detection of extreme values through the redundant representation.

In summary, there is evidence that conventional graphical encoding methods, which have been successfully proven for mono-temporal maps, cannot prevent negative effects caused by the characteristics of the layouts (map series or animation), if not even increase them. The overarching question is whether other forms of encoding are able to reduce the disadvantages.

2.2 Basics of solution approach

The underlying idea of this paper is not to use symbol sizes (such as graduated circles) – instead, it is to change the size of entire spatial units according to value changes. This leads to the concept of Value-by-area Maps, which scale the enumeration units in relation to an attribute value (Dorling et al., 2006; Gastner et al., 2018; Roth et al., 2010). These maps are often considered unusual and attractive (Parlapiano, 2016) but also exhibit distortions or even losses of positional fidelity and pattern preservation (Kronenfeld & Yoo, 2024).

There are several approaches for generating Value-by-Area Maps. One well-known approach and the associated *go-cart.io* tool are described in Gastner et al. (2018).

The sometimes-drastic distortions in Value-by-area Maps can be seen as both an advantage and a disadvantage: On the one hand, distortions can emphasize conspicuous (change) features, but on the other hand, they make searching for specific regions more difficult.

Duncan et al. (2021) suggest interactive elements if such cartograms are displayed electronically. Schiewe (2024) proposed a compromise solution between choropleth maps and Value-by-area Maps – the so-called 'Sponge Maps'. Here, different scaling factors are introduced in order to adjust the reference area sizes for specific needs. The idea is to distort the reference map only to such an extent that the shapes and relations are still recognizable. This principle will be taken up again here – but now for the representation of quantitative changes.

3. Concept

The novel method presented here for visualizing quantitative changes in thematic maps uses the graphical variable 'size'; however, not applied to individual signs or symbols, but to spatial reference areas (typically, enumeration units). For this purpose, the principle of Value-by-area Maps (Dorling et al., 2006) is used, which does not scale reference areas according to real geographical area sizes, but to selected attribute values. For this paper, the tool *go-cart.io* (Gastner et al., 2018) is used for generating respective outputs. For the specific purpose of coding change values, three optional extensions of the Value-by-area Map concept are introduced and described below: Total map size, scaling function, and dual coding. A more detailed description can be found in Schiewe (2024).

In the following, a dataset from the Robert Koch Institute (Berlin, Germany) is used that describes daily Covid-19 incidences for the 16 federal states of Germany (between September 11th, 2021 and April 17th, 2023). To reduce the data set, temporal aggregation was carried out by averaging daily to four-weekly values (called 'periods'). For demonstration purposes a subset of periods 4–8 was generated, which are named periods 1–5 in the following figures for simplification purposes.

3.1 Total map size

The total map size of a depicted period can be changed according to the total sum of change values of all regions – leading to *Total Change Maps*. For example, if the total sum of all attribute values is increased by factor 2, also the total area size (sum of all single units) is increased by 2.

Alternatively, the overall size of the map is kept constantly for all periods by normalizing the individual period values – this is called *Normalized Change Map* in the following. Figure 1 depicts the two variants.

3.2 Scaling

The original approach of Value-by-area Maps uses a proportional scaling between attribute value and displayed area size. This intuitive approach can easily be transferred to the encoding of change quotients from two successive attribute states (v_i, v_{i-1}) to respective displayed area sizes (A_i, A_{i-1}):

$$A_i = \frac{v_i}{v_{i-1}} A_{i-1}$$

Because the sum of area sizes A_i for all enumeration units typically differ from period to period, also the overall size ofs the map is changed (i.e. enlarged or reduced, leading to Total Change Maps). For Normalized Change Maps, the respective individual area sizes have to be divided by the respective total sum of area size of the period.

With Value-by-area Maps, strong distortions and drastic enlargements and reductions of individual enumeration units can occur, which might lead to problems in effective and

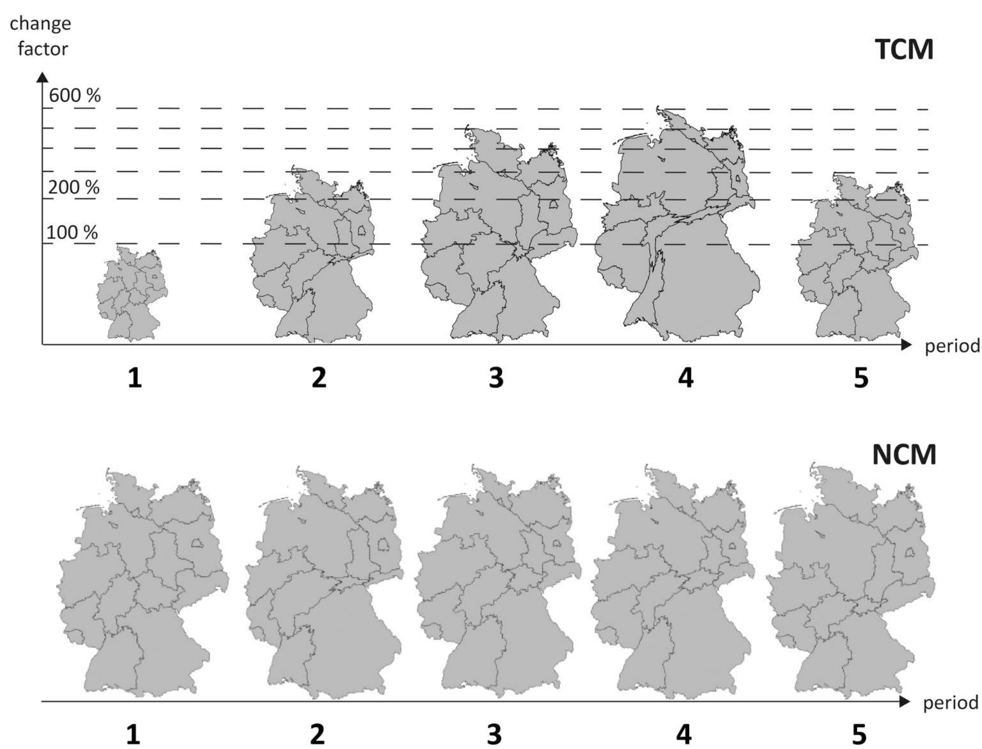

Figure 1. Total change map (TCM; top) vs. normalized change map (NCM; bottom) for five periods.

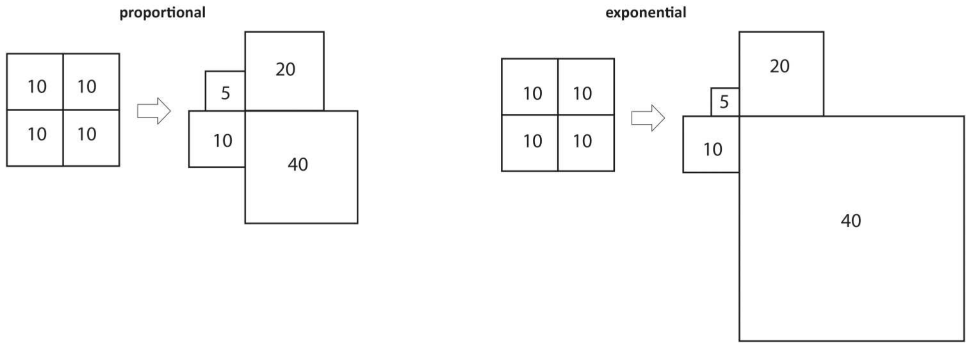

Figure 2. Proportional scaling (left; e.g. value change from 10 to 40 leads to 4-times larger reference area) vs. exponential scaling (right; same value change leads to much stronger area enlargement).

efficient perception and interpretation. For this reason, customizable scaling is introduced as an option, which allows the possibility of avoiding excessive distortions. On the other hand, it is also possible to emphasize ('important') changes. Instead of proportional scaling, various other functions are therefore conceivable – e.g. exponential functions (Figure 2) or range-graded scaling. This possibility of customization led to this concept also being called 'Sponge maps'.

3.3 Dual coding

The Value-by-area approach works without filling the reference regions. This makes it possible to use arbitrary colours for each reference area in order to achieve better differentiation and retrievability. Alternatively, it gives the freedom to integrate colour for any additional attribute. For example, it is possible to depict the original absolute values for each unit (Figure 3). Such a dual coding can be helpful for the interpretation, as the change maps as such do not reflect the absolute values anymore.

In the case of using additional colour lightness coding, a classification of original values v_i is recommended in order to enable larger contrasts and faster recognition. However, the conventional methods (such as equidistant or quantiles) do not necessarily consider the

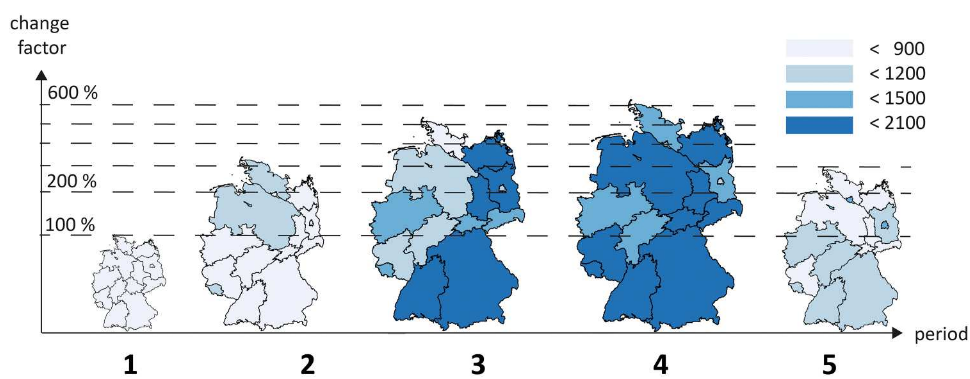

Figure 3. Example of dual coding – unit sizes depict change in Covid incidences, colour lightness represents absolute incidence values.

preservation of 'important' change information as they are placing the class limits based on a data or histogram driven base only. Schiewe (2024) presented a method that explicitly defines and preserves 'important' changes to a certain extent. In a simplified manner, one can require the following (after setting a priori the desired number of classes and respective thresholds for large value changes (Δ_{LARGE}) and rather small changes (Δ_{SMALL}):

- Introduce at least one class break for large value differences $| v_i - v_{i-1} | \geq \Delta_{LARGE}$, and
- Avoid any class break for small value differences $| v_i - v_{i-1} | \leq \Delta_{SMALL}$

4 Study

With the overall aim to test the intuitiveness and usability of the presented extended concept of Sponge Maps, a user study has been conducted by Wolf (2024).

4.1 Study design

The study was conducted as a web-based survey, whereby addressing the participants via different E-mail distribution lists and issuing the survey only in German does not necessarily enable a representative description of the user characteristics. After selecting the responses that were fully completed and showed no anomalies, a sample size of n = 101 remained, with an almost equal distribution of genders and a proportion of two thirds of cartography laypersons (based on self-assessment).

A total of 32 questions were asked, which were presented in a within-subject design. For reasons of simplification, the study was limited to bi-temporal static representations (i.e. a comparison between two periods was required). Various design options (see Sect. 3) were defined as independent variables, while the correctness of answers to questions on the development of certain values was defined as dependent variable.

The blocks of questions were briefly introduced, but the main subject of the study – the changes in size of the spatial reference units – was explicitly not referred to in order not to influence the testing of intuitive understanding. These blocks were framed by questions about the person (gender, previous experience) and the opportunity to make comments in free text fields.

In the following, the results relating to the three design options mentioned above are summarized in aggregated form and interpreted. Unless otherwise stated, the results (especially the differences between parameter settings) are statistically significant. A complete presentation of the study can be found in Wolf (2024).

4.2 Total map size

The basic hypothesis related to the possible variants of the total map size states: The Total Change Map (TCM) allows effective detection of *global* changes, while the Normalized Change Map (NCM) allows effective detection of *relative* changes or comparisons of individual spatial reference units.

An average recognition rate for **global changes** of 67% was achieved in the TCM (Figure 4, left) with both increasing and decreasing global values (i.e. considering the total sum within a period). In view of the unfamiliar and unexplained encoding form, this can be interpreted as an indication of a good cognitive understanding of the

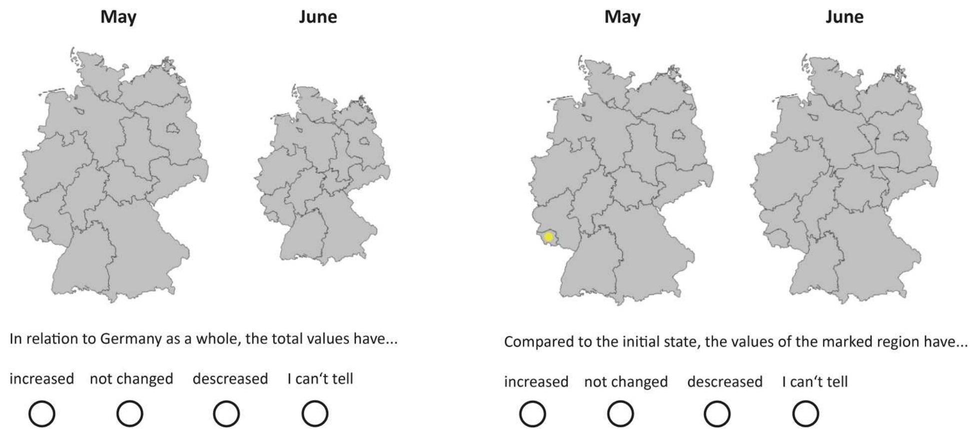

Figure 4. Exemplary questions of the survey regarding total change values (left) and relative changes (right) (translated from the original questionnaire in German).

relationship between value and size change as well as a general suitability of the TCMs for representing global changes.

However, it also became clear that absolute changes in *individual* units cannot be reliably detected within a TCM. If one changes the question in Figure 4 (left) to 'Compared to the initial state, the values in a single region have been … ', the average detection rate was 40%, with strong fluctuations between small regions (poor rates) and large regions – also confirming the aforementioned 'area-size bias'.

For the pure bi-temporal *choropleth* map, which is based on the same data and uses colour lightness for depicting the absolute values for each period, there were 85% correct answers. It is assumed that this significantly better result is largely due to the familiar display form of colour encoding.

A Normalized Change Map (NCM) cannot be used to visualize a global change in values. This fact was not explained in the corresponding questions, yet 84% of the test subjects gave the correct answers ('I can't tell' or 'not changed').

Looking at **relative value changes**, i.e. changes between individual regions, the NCM (Figure 4, right) is significantly superior to the TCM. It has to be noted that results obviously vary with the size differences of a region (the larger the difference, the better the recognition): Recognition values vary between 60% and 81% for NCMs – compared to 37% to 72% for TCMs, taking the same regions into account. Interestingly, female participants answered significantly more correctly than male participants in the detection of relative changes (for both TCM and NCM).

4.3 Scaling

The underlying hypothesis regarding the scaling option is that a proper selection of a scaling function makes changes more obvious and thus the detection more effective.

For three comparative examples (one example shown in Figure 5), an average detection rate of 65% was found for the weakly distorted representations – compared to a significantly better rate of 78% for strongly distorted maps.

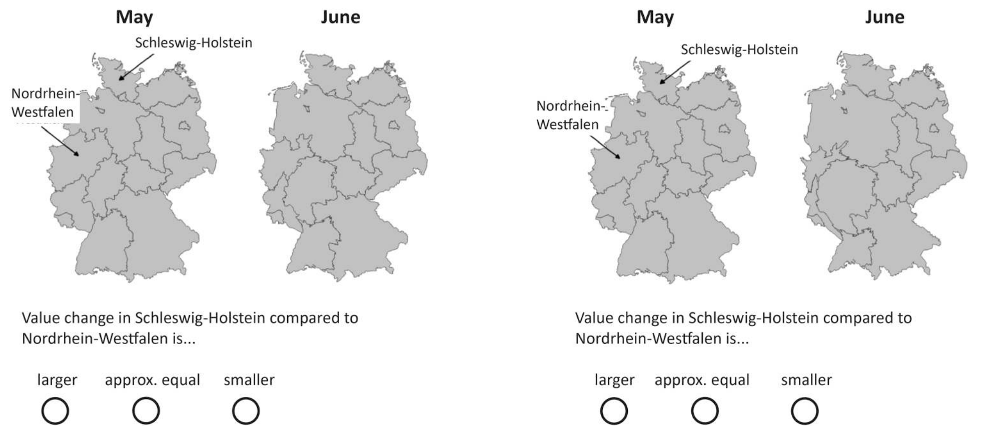

Figure 5. NCMs with different scaling – left: proportional (no amplification); right: exponential (large amplification) (translated from original questionnaire in German).

On closer inspection, the proportion of correct answers differed between the data sets: If the area sizes of two regions changed in different directions ($A_{i+1} > A_i$ and $B_{i+1} < B_i$), the proportion of correct answers was higher than if both regions changed in the same direction ($A_{i+1} > A_i$ and $B_{i+1} > B_i$ or $A_{i+1} < A_i$ and $B_{i+1} < B_i$): Data sets with different directions achieved 89% and 85% correctness, while this rate was reduced to 60% and 64% for the data sets with aligned directions of value changes.

All in all, these numbers confirm the potential added value of the Sponge Maps principle that, however, needs to be applied carefully with respect to underlying data characteristics that, among others, have an influence on the degree of undesired distortion.

4.4 Dual coding

Value-by-area Maps allow the additional encoding of spatial reference areas by colour lightness. As this dual coding option increases the amount of information and complexity,

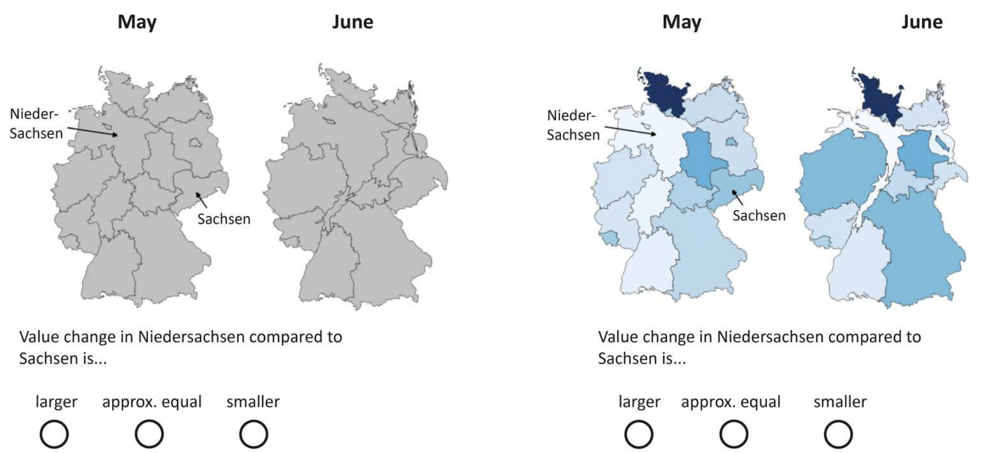

Figure 6. NCMs without (left) and with dual coding (right) (translated from the original questionnaire in German).

the hypothesis of the study is that such a dual coding leads to a less effective perception of differences in change.

The hypothesis was confirmed (78% vs. 73% detection rate for presenting a data set without and with dual coding; Figure 6). Surprisingly, the observed difference between these variants is neither as large as expected nor significant from a statistical point of view.

As mentioned in the hypothesis statement, the general trend has been expected because the additional information makes the map more complex and might even confuse people as in extreme cases, as colour and size might not develop in the same direction: For example, in a NCM, there might an increasing absolute value (leading to darker colour), but also to a smaller unit size due to the fact that the other regions have an even stronger increase of change values. However, it is possible that study participants did not take enough time, so that such problem cases were not even recognized.

5 Encountering the subjectivity problem

5.1 Problem of subjectivity

The concept of Sponge Maps is a form of cartographic generalization – i.e. for reducing, changing or highlighting spatiotemporal information. With the parameters 'total map size' and 'scaling' Sponge Maps can be used to represent different 'messages' accordingly. For example, it can be used to emphasize particularly important changes or changes in small regions (to avoid the 'area-size bias'), or to create general legibility, which, depending on the data set, can also mean a disproportionate reduction in size in order to reduce the typical distortions of these Value-by-area representations.

The multitude of such 'map messages' means that there cannot be one 'right' or 'wrong' map representation. The definition of the purpose is generally the responsibility of the map author, which also entails a risk of subjectivity and even manipulation. In this context it should be emphasized that although it is generally desirable to achieve the most objective and trustworthy representation possible for all maps, the corresponding effort must be weighed up, as this aspect is more relevant for some 'risky' topics (e.g. disaster management) than for others.

5.2 Metadata

In view of these subjectivity potential – which of course also applies to other operations of cartographic design (such as the choice of a map projection) – the creation of transparency is of great importance: With that, the specific purpose ('message') of the author should be explicitly named (e.g. in the map title or in explanatory notes). But it is also desirable that the parameter settings used for the cartographic design are published. The following section 5.3 outlines a corresponding, structured compilation of parameter settings for Sponge Maps that depict multi-temporal geo-data. This can also be seen as a first step towards to the most automated creation of metadata possible in order to keep this time-consuming and unpopular work away from the map author as far as possible.

All in all, this leads to the need for increased generation of detailed metadata that goes beyond the existing standards of the Open Geospatial Consortium (OGC; such as: Catalogue Service, Portrayal Service, TrainingDML-AI Standard Part 1) or International Standard Organization (ISO; such as ISO 19115: Geographic Information – Metadata, ISO 19157: –

Data Quality). The International Cartographic Association (ICA) is also currently making initial attempts to further develop this topic with a Working Group on Standardization in Cartography and a Commission of Ethics in Cartography.

Such metadata (or even non-existent metadata) not only helps to identify 'fake maps', but also represents added value in AI-generated map generation: Instead of filtering suitable maps out of the total amount of all maps for learning or training purposes by interpreting the graphics, access to the metadata is theoretically sufficient to identify suitable items, allowing the generation of 'maps from metadata'.

5.3 Description of sponge map generation

The following compilation of parameters that occur in the course of multi-temporal Sponge Map generation can be seen as a first step towards a set of metadata that is necessary for a transparent description of the workflow. Of course, the overall structure can be easily transferred to other map types that are used for the display of multi-temporal information (e.g. a series of choropleth maps).

The **area of interest** requires the specification of the spatial (enumeration) units – ranging from a single region to the totality of units in the map.

The **time of interest** includes the specification of a time interval (start and end period) and the temporal resolution (lag). Of course, more advanced definitions are possible; however, the simple selection of sequential and equally spaced periods is sufficient for most queries.

Change properties can be described with the help of related (geo)statistical measures (in some cases, by adding necessary thresholds):

- Difference (or quotient) of *attribute values* for selected spatial units within selected time interval: global maximum/minimum, local maximum/minimum (i.e. extreme value compared to all direct neighbours), largest/smallest differences (e.g. expressed by percentiles); etc.
- Existence of *trend*: (monotonous) increase/decrease for selected spatial units within selected time interval), etc.
- Magnitude of *spatial patterns*: Difference of characteristic values of hot/cold Spots, clusters, etc.

The **visualization context** considers the intended map use (e.g. presentation vs. exploration), map user (e.g. layperson vs. experts), duration of presentation (e.g. map in TV news vs. textbook), or the map layout (e.g. map animation vs. small multiples). All these factors have an influence on the design of Sponge Maps for visually

- enhancing change properties (e.g. to highlight certain value differences),
- suppressing changes (e.g. to direct the focus on significant changes only), or
- avoiding confusion (e.g. to reduce distortion effects caused by Sponge Maps).

As an arbitrary example:

- Area of interest: All enumeration units (i.e. all federal states)
- Time of interest: Interval: months 1–5; temporal resolution (lag): 1

- Change property: Largest positive value changes, defined by 90% percentile of all changes
- Number of classes: 5
- Enhancement: Yes – by defining an enlargement of enumeration units for large changes (as defined above) using an exponential function
- Suppression: Yes – by defining no enlargement of enumeration units at all for all other changes
- Avoiding confusion: Yes – by limiting the maximal enlargement of any enumeration unit size to factor 4.

Of course, this arbitrary setting cannot be applied to any data set. In fact, the individual statistical characteristics have to be considered for an individual customization.

6 Conclusions

All in all, the empirical study confirmed the expected intuitiveness and effectiveness of the concept of changing the size of the spatial reference units for displaying changes in values: Shrinking regions point to decreasing values, expanding regions point to increasing values.

However, the detection rates (roughly between 60% and 80%) are significantly lower than those of conventional bi-variate choropleth maps (here: 85%). One reason could be the general confusion caused by the deviation from the known geographical region sizes. Furthermore, choropleth maps are well known, while Sponge Maps are not. In addition, there was – by purpose, in order to test intuitiveness – no further textual explanation of the encoding principle for the test persons in advance. It can be expected that such additional information has the potential to clearly increase the correctness up to necessary values in the order of 80% to 90%.

The added value and special features of the individual design options were also confirmed:

- The different options for selecting the total map size serve to adapt to different issues (TCM for global changes, NCM for relative changes).
- Different scaling functions can particularly emphasize desired change properties.
- Dual coding led to a poorer recognition rate, but this was only slightly worse and not statistically significant, so that this option appears to make sense for uses if more viewing time is allowed and a textual explanation is provided.

There are several directions with regard to future work on the algorithm and the empirical study: It should be noted that the study worked with static bi-temporal examples and possibly did not address a representative sample. Furthermore, no textual explanations were given in advance. These aspects need to be considered for further studies that then also might lead to a more profound comparison to alternative encoding options such colour lightness. In particular, the necessary amount of textual explanations (e.g. given as subtitle of a map) and the interplay with different layouts (map series vs. map animation) are of great interest.

Since the various design parameters can fulfil different purposes, it is also of interest to automatically derive these parameters from the underlying data sets. In particular, we currently develop an optimization algorithm to find a compromise between enhancement and distortion. For this, a certain range of scaling functions and corresponding parameters is introduced – the optimal solution is derived from metrics for enhancement (e.g. described by geometric dimensions in square millimetres between before-after areas) and distortion (mainly related to shape).

Until now, the choice of design parameters was made by the map author, which leads to a certain degree of subjectivity, if not even to the danger of manipulation, in the creation of Sponge Maps. The necessary introduction of transparency begins with the disclosure of the 'message' of the map and continues with the communication of the detailed design parameters. Future work must therefore address the elaboration of existing geospatial standards as well as the development of automatic metadata generation during the map creation process.

Notes on contributor

Jochen Schiewe is Full Professor for Geoinformatics and Geovisualization at HafenCity University Hamburg, Germany. His works are mainly concerned with the development of task-oriented algorithms in Cartography and the modelling and visualization of uncertainties in geo data. He is author of the textbook on 'Cartography' and President of the German Cartographic Society (DGfK).

Disclosure statement

No potential conflict of interest was reported by the author(s).

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