Considerations of Graphical Proximity and Geographical Nearness

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Abstract

"Near things are more similar than more distant things" states Tobler's first law of geography. This seems obvious and is part to much cognitive research into the perception of the environment. The statement's validity for assessments of geographical nearness purely from map symbols has yet to be ascertained. This paper considers this issue through a theoretical framework grounded in Gestalt concepts, behavioral ecological psychology and information psychology. It sets out to consider how influential experience or training may be on the association of graphical proximity with geographical nearness. A pilot study presents some initial findings. The findings regarding the influence of experience or training are ambiguous, but point to the rapid acquisition of affordances in the survey instruments as another factor for future research.

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1 How is geographical nearness related to graphical proximity

Tobler's first law of geography states it plainly: near things are more similar than more distant things [18, 19, 20]. It has become an anchor of a general understanding of space/time phenomena and a primary reference in teaching and research. It expresses a truth about our perceptions of the environment around us [15] that is a cardinal rule for evaluating geographic information. But a question remains to be asked: How does it apply to people's perception of nearness using only map symbols? The answer is surprising: We do not know. There has been just no internationally published research to-date that assesses how the graphical proximity among map elements corresponds to geographical nearness in Tobler's sense. This paper draws on socio-cognitive approaches from psychology since the early 20th century that considers how people rely on both cognitive and social faculties and knowledge in spatial comprehension. It offers a theoretical foundation for the exploratory study of how people understand the graphical proximity of spatial representations – geovisualizations, usually maps. This question is relevant for GIScience and the many daily and emergency applications of geographical information. Geovisualizations make up the dominant form for the representation of spatial information of geography [11]. Improving map-based geovisualization tools and augmented

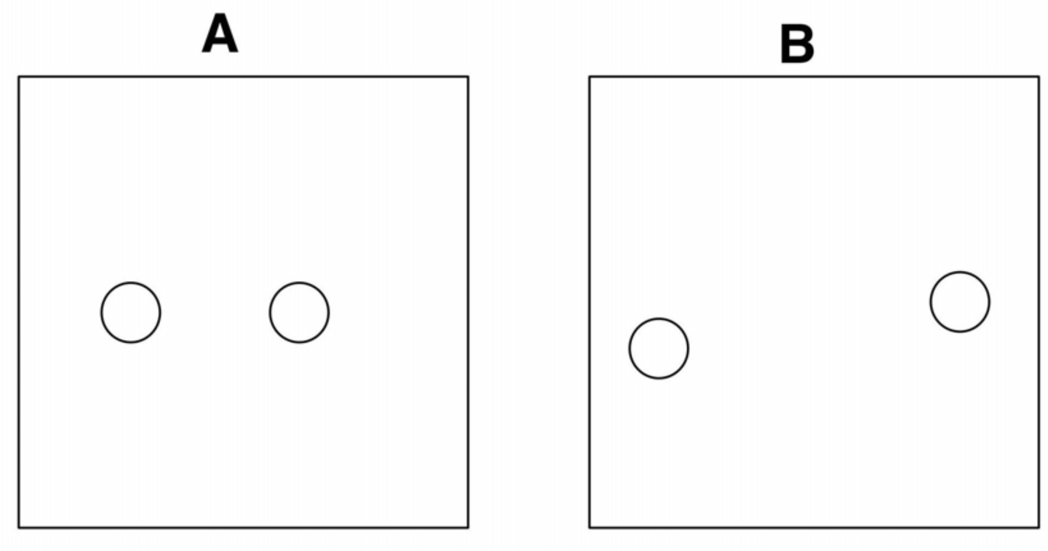

Figure 1 Already recognized over 100 years ago in the first Gestalt studies our minds identify without conscious effort graphic elements that are closer. This A/B situation of object pairs near/ further is used in the pilot study reported later in this paper

reality used for mobility and navigation presents multiple possibilities for improvements. Errors and distortions are also commonplace. To show things and events [10] at all geographic scales, from an aerial photo of an urban block to an animation showing wind speeds and directions around the earth, we rely on graphical representations. Maps, with their evolving meanings that reflect changes in technologies and media [3, 13, 4], remain GIScience's most common form of representation. The graphical proximity of things or events seems to preattentively (perception before conscious knowledge) indicate a geographical nearness. But does that perception and the following understanding come from intuitive understanding alone? How do training and experience impact the perception of graphical proximity and its translation into geographical nearness? A common understanding is that we see proximity immediately and intuitively – which means even before we think about what we see our mind assess the image and is aware of their proximity [26].

It is powerful and useful capacity of the human mind's visual faculties. However, to place the abstract question's relevance more clearly for GIScience, how does the preattentive perception of proximity among elements in a geovisualization reliably correspond to geographic nearness? We learn perhaps much of this, but how much of this is nurture and how much is nature? Indeed, the visual perception of the mind can be readily fooled. Illusions (such as shown in Figure 2) highlight that our perception is continuously subject to biases. Cognitive and social psychology have since the Gestalt psychology studies almost 100 years ago begun to shed considerable insight into the perception of graphical phenomena. From these studies, we know that proximity is a vital aspect of the mind's faculty in preattentively comprehending the world around us. This finding is evident from behavioral studies of visual perception. However, the many studies have focused very little attention looking into how graphical proximity corresponds to an understanding of geographical nearness.

Based on research into socio-cognitive processes of visual perception, this paper sets out to offer a tentative framework and some initial empirical evidence for the relationship between graphical proximity and geographical nearness to suggest the importance of distinguishing

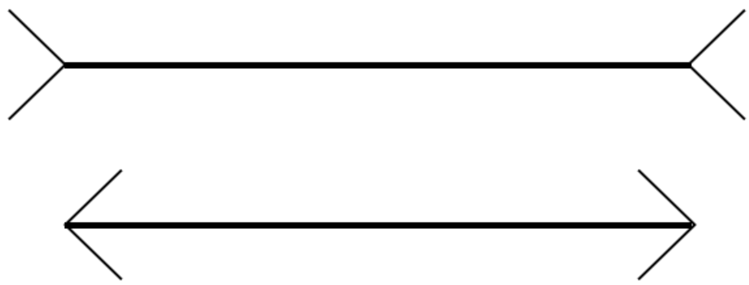

Figure 2 Example of preattentive vision capabilities prone to biases. We see that the upper line is longer, but both lines are actually the same length. The Müller-Lyss illusion shown here belongs to the many visual illusions studied over more than 100 years. This well-known illusion was first published 1889 by Franz Müller-Lyer in Optische Urteilstäuschungen. Archiv für Physiologie Supplemental pp. 263–270.

graphical perceptions of nearness from visual perceptions of nearness in GIScience research. The focus of this paper is on the conceptual review with some preliminary study data that offers a basis for further research and a test of an empirical Bayesian approach to analyzing experimental data. This paper is an initial foray into a complex area that multiple fields of science (psychology and neuroscience perhaps most commonly) have considered over more than 100 years. The concepts for this paper are rooted distinctly in research associated with behavioral psychology but follow concepts from informational psychology [5]. Presentation of these concepts make up a significant share of this paper and determine its structure. The next section of the paper describes the theoretical background in work on socio-cognitive studies of spatial perception and reviews research that refines the Gestalt concept of proximity. The following section provides a detailed presentation of the methods used in this study. The results of a small test are presented, analyzed and reviewed in the next section. The conclusion summarizes the findings of this study and points to a future avenue of research to better understand how people perceive graphical proximity in geovisualizations and comprehend it as geographical nearness.

2 Some Background: Nearness, Proximity, Biases and Ecological Psychology

Considering how people understand geographical nearness through representations that render geographical things and events as graphical elements and compositions build on psychologicalbehavioral research conducted over more than the past 100 years. Summarizing the breadth and depth of that research lies plainly beyond the scope of this paper. It provides a more limited literature review of relevant work in GIScience and cognitive psychology with some pointers to older seminal research. Central concepts of Gestalt, behavioral, ecological and informational psychology complement this work by taking up the concepts of affordance, visual clustering/patterns in visual comprehension, and pre-attentive patterns in that broader sense. Informational psychology takes this research and situates it in a contemporary information processing framework. The emphasis of this article on the connection of a theoretical framework to an empirical study also facilitates development in further studies.

Figure 3 Figure 5 from Wertheimer's 1923 paper shows one of the more simpler configurations that illustrate the Gestalt concept of proximity. Thirty additional figures increase complexity and broaden the focus to issues of patterns and isomorphism in his search for laws for the whole (Figure available at http://psychclassics.yorku.ca/Wertheimer/Forms/forms.htm.

2.1 Tobler's law review

The concept behind Tobler's law is to develop a maximum of scientific utility from the simplest as possible statement [20]. Much has been considered about the philosophical issues implicit in this approach. For the intents of paper, drawing on research published by the first Gestalt theorists, the emphasis on simplicity is seen to have considerable value in its lucidity. As Tobler's law of geographical nearness appears to find valence for many users of geovisualizations, the parallel is relevant in seeking to evaluate the question how perceptions of graphic poximity correspond to the understanding of geographical nearness. This research focuses on understanding how people relate graphic proximity to geographical nearness in the use of geovisualizations.

2.2 Gestalt principle of proximity review

To ground an empirical understanding of graphical proximity and geographical nearness, graphical proximity, a central Gestalt concept, proximity, then in the positivist spirit referred to as a law, but now seen more as a rule, requires some review. Widely known work by Wertheimer, Koffka, and Köhler on Gestalt proximity belongs to the foundational work on Gestalt theories. The concepts have since been studied and further elaborated in neuropsychology [27]. Wertheimer's seminal work on Gestalt concepts, begun in 1912 and primarily published in the 1920s sought to define how visual perception is organized. His 1923 paper established several rules, including the gestalt law of proximity. In its standard formulation, perceptual proximity led to the mental association that closer elements are more similar than distant elements. I call it in this paper graphic proximity, as this and other Gestalt factors interact. It also stands in conjunction with Gestalt rules regarding grouping and similarity. Wertheimer is focussed in his paper on scaling empirically established observations to more general laws about patterns and assertions about the whole's relationship to the part. These later points were already considered more tenuous, and many derivatives of this work ensued soon after their publication. As they all bear the name Gestalt theory, without detailed archaeology of their development and distinctions to clarify their development, an overly complex and also contradictory body evolved.

Over time, neuroscientific and psychological behavioral research evolved from the original Gestalt rules. These developments are relevant to the theoretical framework used in this research. Although at first the search for general laws of form dominated Gestalt research, after its original widespread acceptance of its insights, critiques from positivists, dialecticians, and materialists regarding its mentalist and idealist tendencies led to Köhler's explanation of gestalt research as the isomorphism based on electromagnetic and thermodynamic theories [27]. The conception of an isomorphism between brain states and perception remained dominant later in the 20th century, but more recently has since become far more sophisticated, although it generally follows behavioralist traditions. Although Gestalt research was not of much significance following World War II, due to the failure to establish clear and workable rules of visual perception, it remained significant in many professional fields. It became in various interpretations a tractable framework, for example, to introduce visual design concepts or holistic dimensions of cartography without embarking into the theosophic believes that came to dominate modern art, e.g., as seen in the writings of Paul Klee and Wassily Kandinsky [2].

In behavioral psychology, Gestalt theory remains a conceptual basis for studies of visual clustering and patterns, and in neuroscience, studies of preattentive patterns have influenced recent developments of more advanced theories of visual perception [25]. Ann Treisman has conducted many studies that examine how attention impacts grouping and binding [22, 21]. Other neuroscience studies regarding these matters, for example [17], provide empirical evidence that attention is not decisive in preattentive grouping. Colin Ware in his information visualization research has built nonetheless on the preattentive concepts to advance visual designs for tunable action maps that take human's innate grouping of visual elements in the environment to assist augmented reality navigation [26].

While the origins of these approaches to visualization go back to insights from the original Gestalt theorists, it is worth pointing out that Gestalt research on behavioral matters was also influential for later work of Daniel Kahneman's and Amos Twersky's that led to the development of prospect theory [12, 24]. Its relevance can be seen in the influence of Gestalt researchers work identifying visual illusions that reflect biases in vision (see Figure 1) and their research into biases in cognitive decision making. Gestalt theory also was a starting point for other influential studies. Research into cognitive mechanisms of visual perception remains an active scientific field.

2.3 Gibson and ecological psychology

Among psychologists focused on visual perception following on Gestalt research, J. J. Gibson's lifetime work in this area has had perhaps the largest impact. While impossible in the scope of this paper to consider its breadth and depth, it is relevant here to point out how Gibson's research starts with the behavioral insights of Gestalt research with a more thorough experimental-based development of theories, here labeled ecological psychology, which advanced the understanding of visual perception in a significant degree. J. J. Gibson's affordance concept has been widely used in GIScience and other fields [9, 8]. The nuanced way it is conceived of in his ecological psychology is central to understanding how people associate intuitively perceived graphical proximity with geographical nearness. In agreement with Kahneman and Tversky's behavioral psychology framework, its broadening of cognitive considerations situates vision in a system which includes ambient, accessible information in an ecological sense: "We are told that vision depends on the eye, which is connected to the brain. I shall suggest that natural vision depends on the eyes in the head on a body supported by the ground, the brain being only the central organ of a complete visual system." (Gibson, 1984, p. xii]. While at the neuroscientific level of analysis cognitive processes of vision are encapsulated by brain activity, this approach broadens the scope to consider both nurture and nature factors. Vision, following Gibson, is an information-based process with vision central to activities that implicitly and explicitly involve assessments of the perceivable opportunities for action in the environment. Affordances are these opportunities. We have come to tend to think of them concerning product design and unobtrusive, even invisible, the inclusion of abilities for the pragmatic implementation [16]. Following Gibson's ecological approach, they are conceptual instantiations of specifying information that a viewer draws on to perceive and comprehend an image. In an example related to geovisualization, a hypothetical map showing the air freight volumes at the 50 largest airports of the world, would likely show the freight volumes (after standardization of the data using the graphical variable size [1]) with outlines of national political borders including their names to facilitate speedy identification. This symbolization provides an affordance for readers of the map. The projection chosen for this map would be relevant as distortions common in the widely misused Web Mercator projection could impact the geographic associations that readers make about distances and areas. In this sense, the perception of geographic nearness through graphic proximity involves how people preattentively see and how we passively and actively come to understand the affordances in a geovisualization. Improved processes of intuitive visual perception coupled with a reduced effort of making sense [23] make for useful geovisual affordances. How graphical proximity, a fundamental Gestalt rule, affords the visual understanding of geographical nearness is a good starting point for distinguishing nurture and nature factors in visual perception. Developing an ecological understanding of visual biases and mental biases through the study of affordances used in geovisualization can aid in understanding the influence of preattentive and learned factors in the visual perception of geographic nearness in geovisualizations. Graphics-based visualization, affordances on which geographic understanding of nearness is based, should better be called geo-graphics in this sense.

2.4 Towards a theory of geo-graphical nearness

Building on these conceptual considerations regarding visual perception, the tentative theoretical framework advanced in this article is related to the research question about the relationship between perceptions of graphical proximity and geographic nearness. Its formulation in this first iteration, following Tobler's reflections, begins with an acknowledgment that theories are tools [7] that reflect the scientific, social and cultural contexts that they are created in. Acquired geographical understanding that conflicts with mapped representations is a different issue that rests on similar roots and concepts as this study focused on proximity/nearness. In any case, considering how a geographical understanding of things or processes achieved through understanding geovisualizations is different, from the understanding arrived at through direct experience, remains a relevant and valuable topic. Biases in geo-graphical understanding are complicated, lurking in all mental aspects of perception and comprehension. This work, given its narrow empirical basis, might be seen as a first and tentative attempt to identify biases and from their resolution advance GIScience in this areas. Since the data and theoretical concepts reported here are underdefined, the methodological implementation in the explorative study presented in section four of this paper relies on Bayesian statistics to consider and evaluate possible relationships between graphical patterns and other factors. The conceptual underpinnings build on information-based approach in psychology with a similar methodological process approach that Bayesian statistics align with. Proximity, in this sense, can be understood in the context of visual clustering, esp. Into patterns (Ware 2010, p. 58). De Wit et al. (2015), working directly from an information psychological refinement of Gibson's work established in their empirical work with visual illusions that selective attention influenced the use of specifying (task-specific) and non-specifying information in the perception of visual illusions. In summary, concepts of Gestalt rules, empirical behavioral, ecological and informational psychology ground concepts of affordance, visual clustering/patterns in visual comprehension, and pre-attentive patterns to develop a socio-cognitive understanding of visual perception and visual comprehension. Informational psychology concepts move this understanding and situate the framework for understanding how people perceive graphical proximity as geographical nearness to a cognitive information processing framework. Reformulating the research question based on this theoretical framework, the conceptual distinctions between perception and comprehension are relevant for examining how training or experience leads to recognizable specifying information that viewers draw on in the perception of graphical proximity as geographical nearness. A simple assessment of the validity of this connection in the pilot study seeks to establish whether a relationship between training or experience to the perception of geographic nearness is evident.

3 Experimental Design and Methods

The explorative research for this paper relies on Bayesian methods. Bayesian methods have found in GIScience interest and uptake for research in semantics, land use modeling, and spatial statistics. This paper utilizes Bayesian methods with their strengths for explorative research to operationalize the tentative theoretical framework presented in the previous section, an application more often seen in psychology and other social sciences.

3.1 Bayesian Methodology Background

For this explorative research Bayesian methods are well suited in comparison to statistical techniques relying on frequentist statistics. Bayesian methods are ideally suited to identify and evaluate relationships in data as it produces results that reflect additional data. At the risk of oversimplification, Bayes Theorem focuses on elaborating an understanding through the evolving statistical testing of data that refines understanding of the phenomena. In statistical terms, Bayesian methods produce posterior distributions that researchers have understood speak to issues with polling, confidence intervals and p-values in classical frequentist statistics [6]. The prior belief about the data $P(A)$ is calculated with the normalization constant $P(B)$ and the conditional probability $P(B|A)$, as in Bayes' Rule:

$$P(A|B) = \frac{P(B|A) * P(A)}{P(B)} \tag{1}$$

In other words, Bayes' Rule is the posterior probability equal the likelihood times the prior divided by the normalization constant. The application is wide-reaching in helping develop statistically grounded insights. For instance, this allows new observations, implemented as measures, to be introduced and modify the prior known distribution assuming a meaningful relationship between prior data and new data.

3.2 Explorative Study and Bayesian Methods Used

The use of Bayesian methods will be helpful in assessing the instruments and for further refinement of this data. The data collected for the study comes from an online survey developed with the software suite Lime Survey (limesurvey.org). It was analyzed using classical and Bayesian methods available in the open software package JASP from the University of Amsterdam (JASP-stats.org). Data were collected in October 2017 from students in the Master's level Critical Cartography seminar who had received an invitation with the URL. 10 students, 5 male, 3 female and 2 unknown, completed the survey. The ages of the participants ranged from 24 to 51, the mean age of the group was 30.4. The limits of the sample size are significant. Nonetheless, given the focus of this article, the small n remains helpful for a pilot study. The survey consists of five background questions and eight A/B comparisons using pairs of images. Each A/B test consisted of two identical images except for the location of two circles or diamonds in each. These symbols were placed in different distance to each other. Participants were requested to determine in which image the two circles were closer together without using additional aids. They were instructed at the beginning of the survey that the time for them to indicate a response was relevant to the study.

4 Explorative Study Analysis and Critique

The images in the online survey instrument for an invited group of participants presented pairs of images that varied in graphical complexity and geographical context. Some included random graphic elements, others used outlines of countries, and some included both random graphic elements and country outlines (see Figure 8). Following the central research question, the survey focused on assessing differences in the times it took participants to identify the closest graphic proximity between two elements from each pair of images while increasing the number of other elements and adding a geographical dimension to the graphic. The key instrument operationalized in the survey is if graphical proximity affords the visual understanding of geographical nearness. The results can be analyzed with data on experience and cartographic/GIS education. Additional questions about training and experience can shed insights into these factors influence on the experimentally established behavior and help understand ecological visual biases and mental biases.

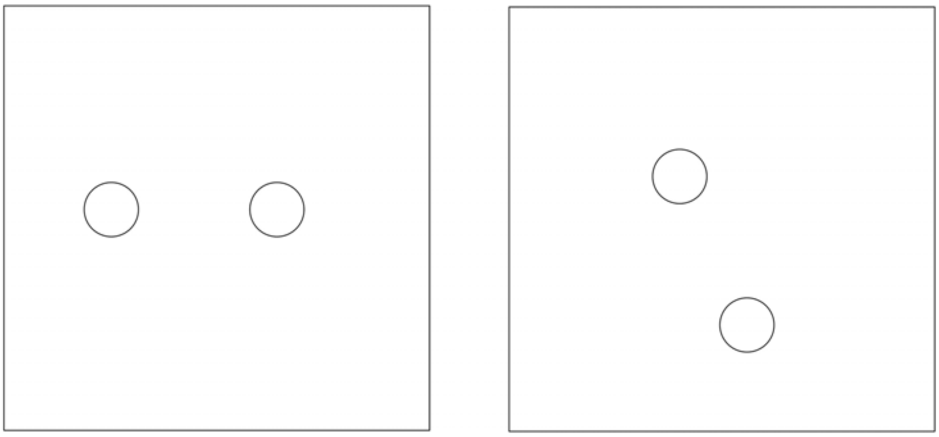

Figure 4 Image pair used for the first comparison by study participants.

The presentation of the study commenced with an overview and presentation of some summary statistics. Most of the ten survey participants had cartography/GIS courses or experience. Two indicated have more than 3 years experience, and six had 2–3 years experience. The other two respondents had no or 1 year of experience. As to be expected, most of the students (5) had 2–3 courses in cartography/GIS; two had one course, and three had had 3 or more courses. Correspondingly, the majority of participants recognized a set of widely-used terms in cartography/GIS. Interesting is the ambiguity in the relationship between experience and courses to the knowledge of these terms despite general indicated knowledge of the terms. Of 14 terms, only the terms reliability and visual variables were known by two of the respondents. Typography and raster were the only terms known by 7 of the participants. The contingency table analysis of these responses regarding years of experience also showed no strong positive relationship. Curiously, the contingency table analysis of the responses regarding the number of cartography/GIS courses taken pointed to an increased lack of knowledge of these four terms among participants who had taken 1–2 courses in contrast to the students who had taken 1 or 3 or more courses.

The times taken by participants to identify the image out of two that showed the more considerable distance between two circular or two diamond shaped elements is the key attribute of the studies to consider. While the variance in the response time is noticeable, generally, even with increasing complexity of the images to compare, the response time

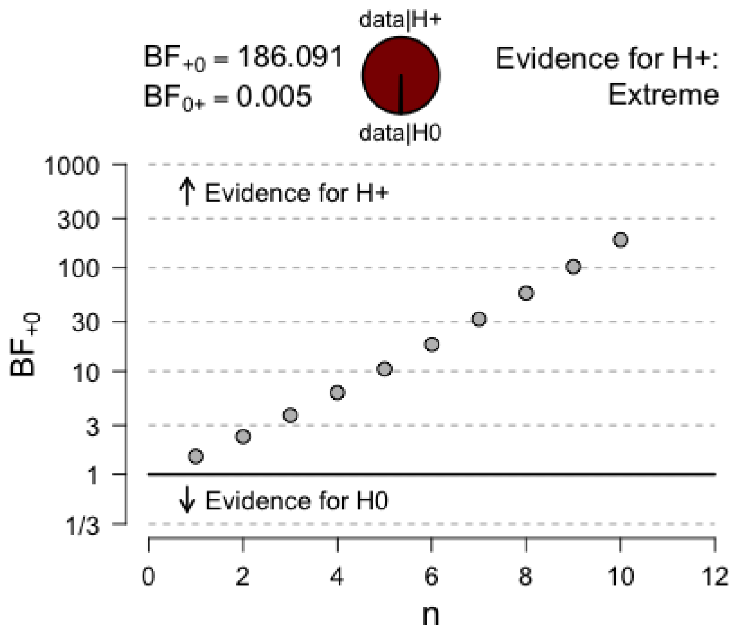

Figure 5 Graphic summarizing the Bayesian sequential analysis for figure pair one from JASP. The result offers extreme support for the alternative hypothesis, increasing in reliability as each response is calculated.

declines. The minimum response time for all eight image pairs drops from 9.4 to 5.6 seconds and the maximum decreases from 40.68 to 16.81. The means and standard deviation values also decline. These results suggest a learning effect having a substantial impact on the results. This issue is significant and considered later in greater detail.

4.1 Analysis of the Pilot Study Data

A Bayesian binomial analysis was applied to the responses to establish whether participants relied on guessing to complete the survey. The majority of responses were correct, but some figure pair comparisons of up to two participants failed to identify the figure with the closest pair of objects. First, though, the first pair of figures, which all participants identified correctly (see Figure 4) offers a benchmark of Bayesian binomial statistic for assessing this statistic for the figure pairs that were not consistently correctly interpreted. The very high Bayes Factor$_{+--0}$ of 186.091 is substantial support for the alternative hypothesis that participants were not guessing in their interpretations.

In image pair three, one person incorrectly misinterpreted the closer pair of elements or incorrectly chose the image, which placed the two elements further apart. The Bayesian sequential analysis of the Bayesian binomial statistic shows this in the chart and in the Bayes Factor+–0 of 18.509. This lower Bayes Factor suggests this figure pair could be more challenging to interpret.

The final Bayesian binomial analysis considers the responses to image pair 5. Analogous to the analysis of figure pair 3, the sequential analysis chart shows how incorrect interpretations of proximity have a negative impact and strength of the Bayes Factor.

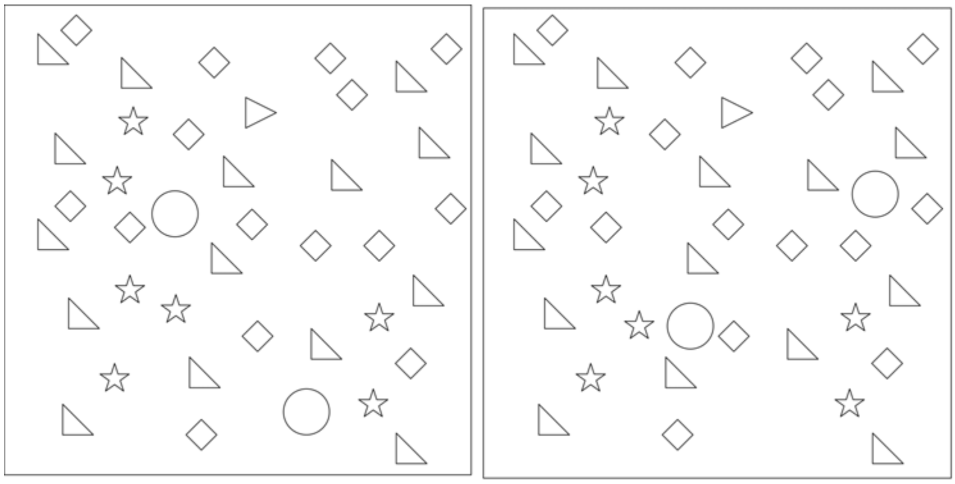

Figure 6 Image pair used for the third comparison, which include complex arbitrarily placed graphic elements.

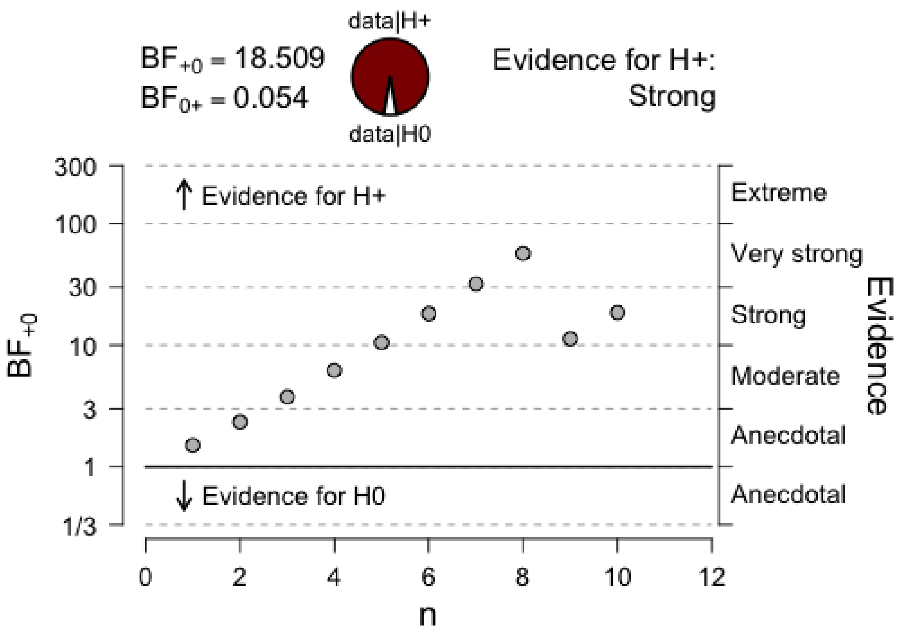

Figure 7 Bayesian sequential analysis chart for figure pair three. The result offers strong support for the alternative hypothesis, increasing in reliability until the image with more distant elements was selected by participant.

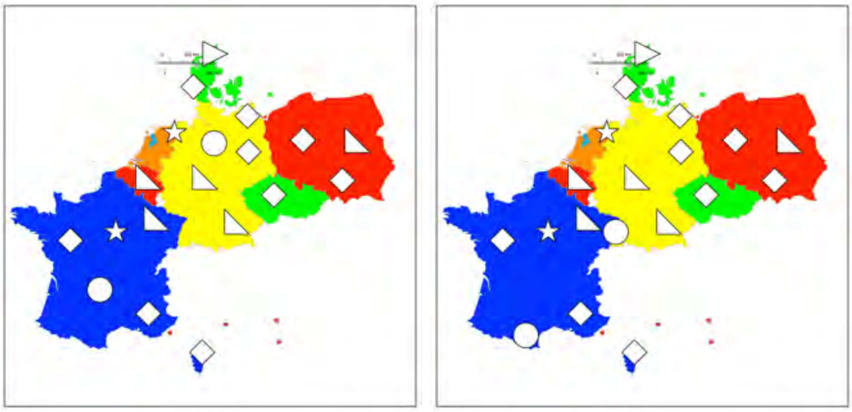

Figure 8 Image pair used for the fifth comparison, which include complex arbitrarily placed graphic elements.

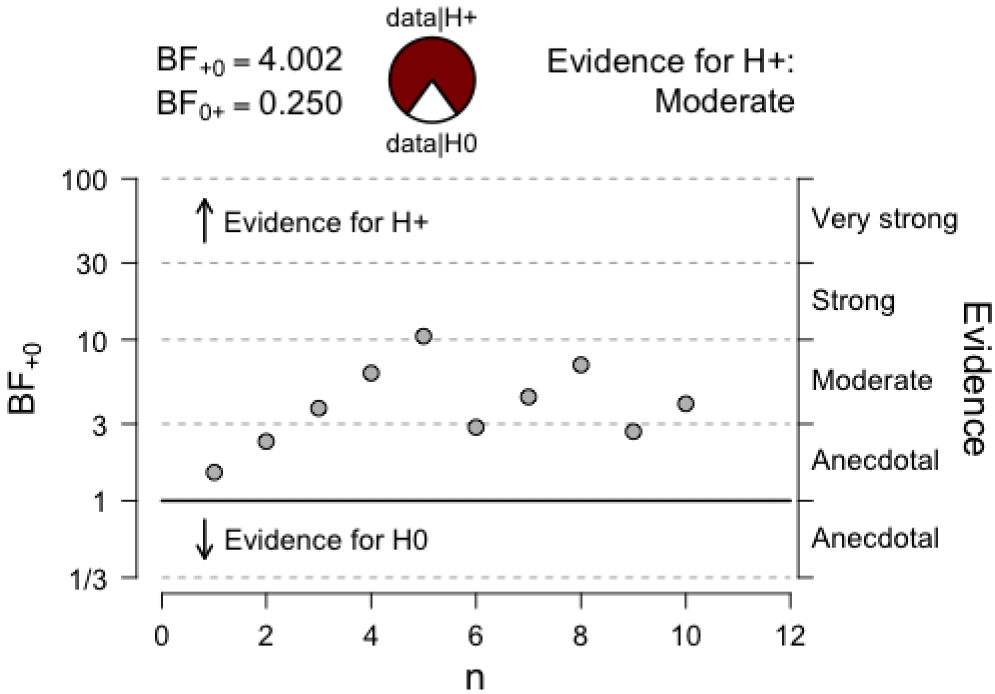

Figure 9 Bayesian sequential analysis for figure pair five. The result offers moderate support for the alternative hypothesis, the Bayes Factor increasing and decreasing in reliability as each response is calculated.

Table 1 Response time (in seconds) statistics for all participants from JASP.

	Q 1	Q 2	Q 3	Q 4	Q 5	Q 6	Q 7	Q 8
Mean	22.90	44.30	30.52	26.80	23.38	13.70	11.38	10.78
Standard Deviation	11.28	56.08	26.20	21.37	9.15	6.08	5.97	3.76
Minimum	9.49	9.19	10.68	8.65	14.44	6.50	6.43	5.60
Maximum	40.68	183.3	99.14	73.62	40.61	24.13	23.88	16.81

4.2 Impacts of training and experience

The Bayesian binomial analysis helps assess the reliability of the interpretations and the presentation in the sequential analysis charts documents the strength of Bayesian analysis in exploring data. With this small data set the effects are not especially pronounced, but in future work with much larger data sets Bayesian analysis will be of great assistance. The significantly reduced response times among all participants suggest that immediate learning of the affordances available in the study instruments is of considerable impact.

4.3 Bayesian correlation

As a final set of Bayesian analysis, the Bayesian binomial analysis presented above suggests that some image pairs were more complicated to interpret. Did they require more time to analyze? Did training or experience impact the response times? Did immediate learning of the affordances influence the response times despite increasing graphic and geographic complexity in the image pairs? The results of the statistical analysis are inconclusive. The standard deviations in table 1 above suggest that lack of clear associations between participant response times and image pair complexity. The Bayes Factors from the Bayes Paired T-Tests comparing response times from figure pairs with an imperfect identification of the image with the closest pair of elements varied in direction and strength.

As pointed out at several points in this paper, but worth repeating and emphasizing here, the sample size of 10 is a great limitation to considering the relevance of the study's results. The insights from the explorative analysis, however, clearly point to the need for improvements in the methods and instruments beyond increases to the sample size, which will be discussed in the next and final section of the paper.

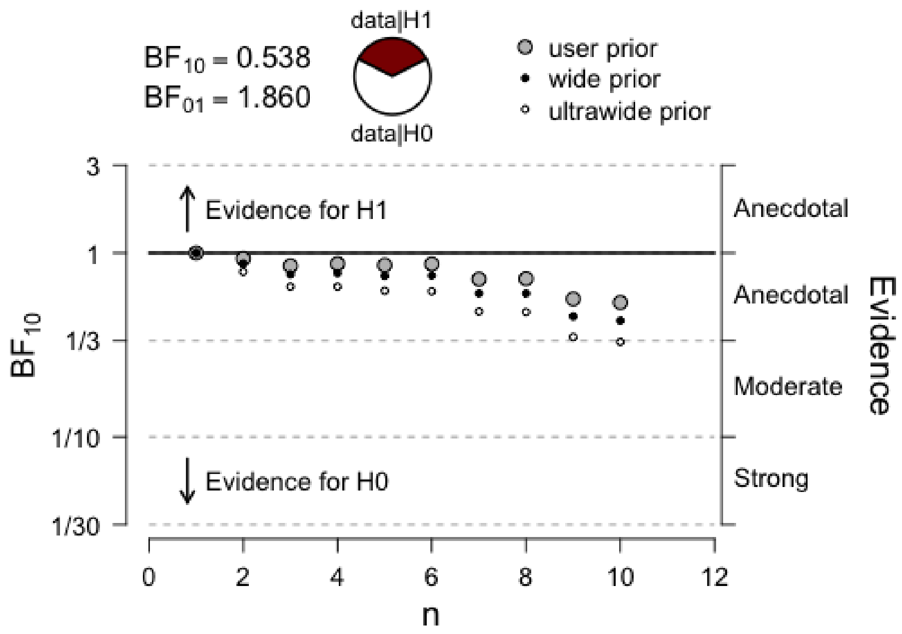

Figure 10 Sequential analysis of Bayes Factors chart comparing response times from image pair three and image pair five.

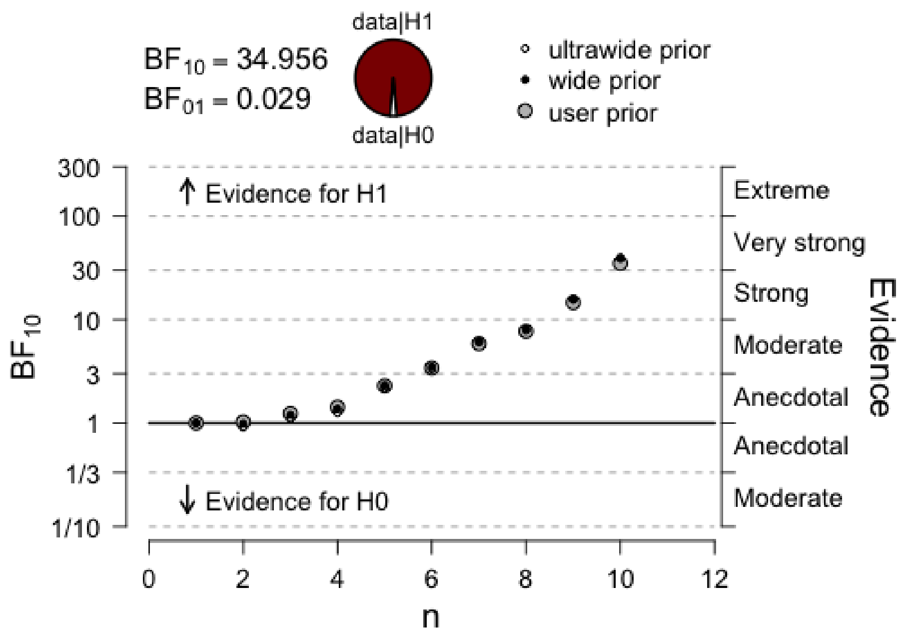

Figure 11 Sequential analysis of Bayes Factors chart comparing response times from image pair five and image pair seven.

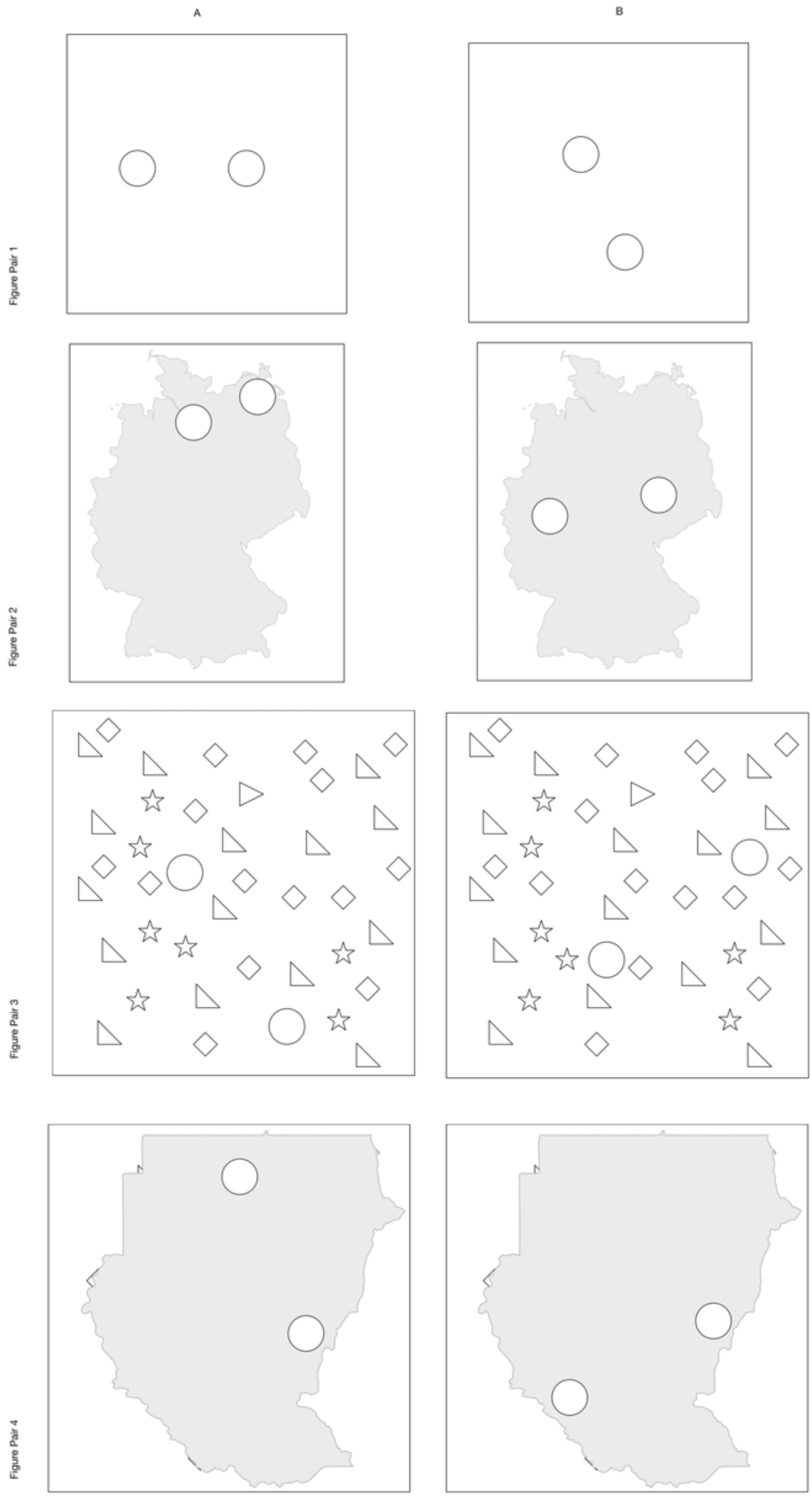

Figure 12 Figure pairs 1 - 4 used in the online survey (not to scale).

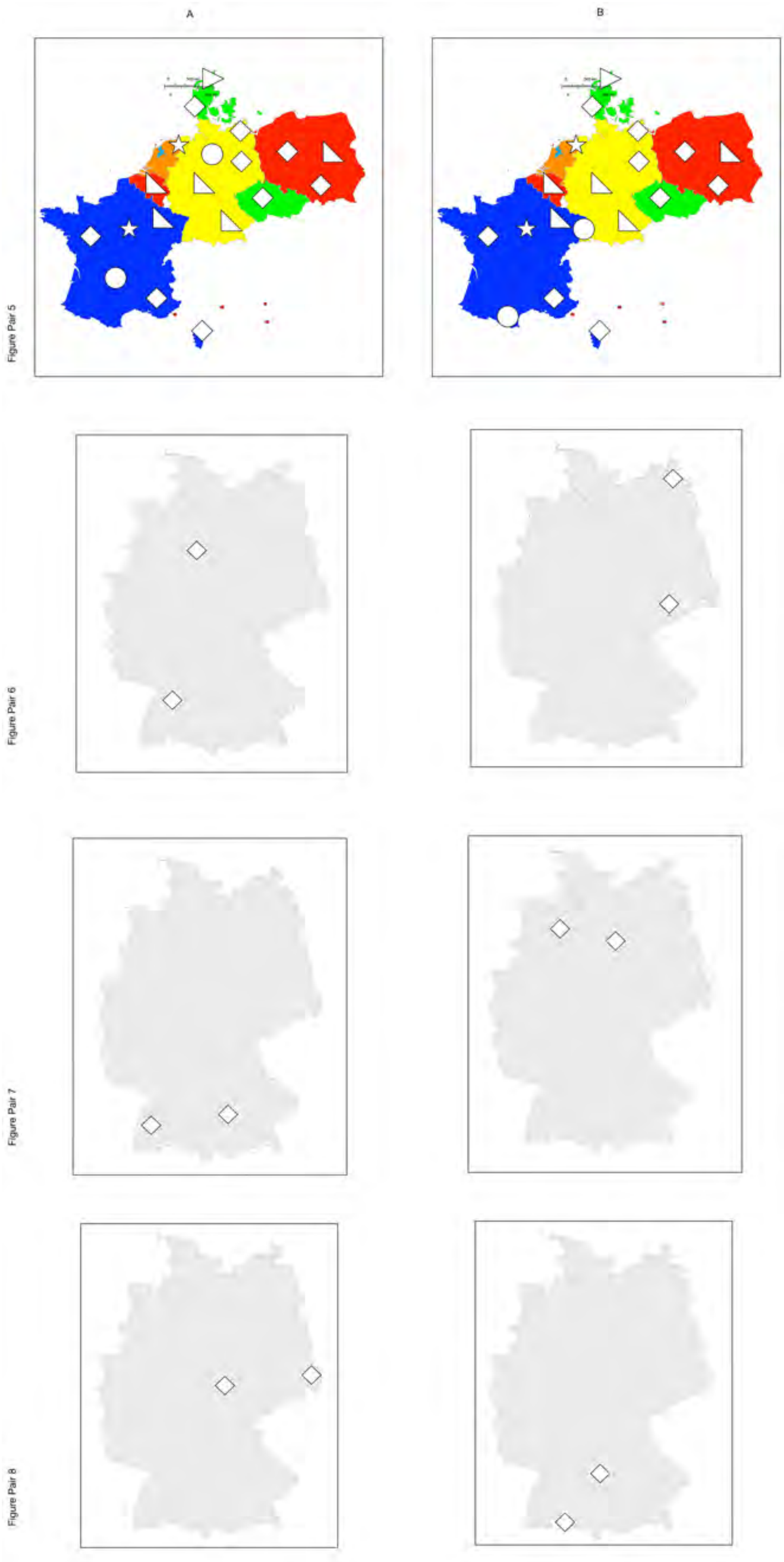

Figure 13 Figure pairs 5 - 8 used in the online survey (not to scale).

5 Conclusions and future research

The results of this explorative study suggest that an understanding of geographic nearness from graphical proximity, and thus Tobler's first law of geography, involves more than intuition in work with geovisualizations. The theoretical framework used in this research seems robust for this research which involves cognitive and social dimensions. The methods and instrument need further development for continued research to better account for preattentive grouping and acquisition of affordance while taking the study. The reduced response times identified from the pilot study data can be explained by the acquisition and application of affordances arising from learning how to make sense of the survey image pairs efficiently. Whether this interpretation is true remains to be verified through future research.

It remains essential to gain a better understanding of the how people come to understand graphical proximity and geographical nearness in geovisualizations. The starting point is already there. The over 60 year old, but then prescient and still relevant, insight from Herbert Bayer to refer to the special and often exceptional capabilities of graphics in geographic communication by separating with a hyphen geo from graphic (geo-graphic) emphasizes how graphic elements and their composition involve different visual perceptions than reading text or even environmental perception. The theoretical framework resting on Gestalt concepts and ecological psychology shown as the foundation for exploratory research presented in this paper suggests geographical nearness is more than an intuitive deduction from graphical proximity. Instead, the two modes of perception and comprehension intertwine in still to be understood ways. The pilot study results suggest in agreement with Gibson that the human mind learns very rapidly how to apply preattentive affordances to visual tasks. The evidence collected for this study does not make clear to what degree training in spatial thinking may be a significant factor in this learning and to what degree experience is a factor. Future research should explore the degree to which developing and applying orthogonal and absolute coordinate reference systems may influence the mind's transformations of graphical proximity to geographical nearness.

The development of these affordances may profit from considering research by Ann Treisman and colleagues on patterns and pre-attentive perception or tunable mental images [26, 21]. It seems possible that both training and experience lead to enhanced mental faculties that tune the post-attentive process of visual perception using acquired patterns.

While open for continued study and refining the theoretical framework, these exploratory results point that geo-graphic nearness understood from graphics is separate from the geographical nearness concepts intrinsic to way-finding and environmental perception. A conjecture about this difference to consider in future research seems straightforward: A geographic visualization provides fundamentally different affordances to the point of producing biases and even distorting our environmental knowledge. In contrast, geographic concepts seem probably based on stronger cognitive concepts. Learning seems essential to the capacity, and hence social and cultural factors become relevant. A known place geographically close to us, in, for example, the sense of measurable distance, maybe still be nearer yet in our understanding of graphic proximity, e.g., topological maps of urban transportation including Harry Beck's famous map of the London Underground network. This difference is relevant in many daily and emergency situations. The results from continued research into these differences can lead to a better understanding of the socio-cognitive mechanisms how people understand proximity/nearness. Future research should consider the relevance of these mechanisms to help address accessibility issues for specific requirements and needs, e.g., people with disabilities or seniors. Another aspect for future research is consideration of temporal aspects in the use of graphic geovisualizations including a more realistic study of the use of maps, e.g., the consideration of travel modes to gain more insight into map reading activities pursued in relation to the reader's goals and the functional support of a map. Ware's tunable action maps seem here to be a useful reference to consider also how naive geographical concepts contradict common mapped presentations, e.g., the experience that Reno is further west than Los Angeles.

The tentative findings are not conclusive and require improvements to the experimental design that accounts for the tentative findings and methodological issues the preliminary work raised. Improvements to the survey instruments used in this exploratory research need to address several points. First, is a research design that allows the learning of the survey instrument's affordance to be measured. Second, the difference between types of image pairs needs to be analyzed and accounted for in the statistical analysis. Third, the number of participants needs to be significantly increased.

To summarize the study and its relevance to GIScience, people in the survey reported here learned how graphical proximity corresponds to geo-graphical nearness, establishing specific cognitive mechanisms in the context of improvements to the methodology regardless of the defined task. While the graphic format and media are relevant, an acculturated, acquired sense of distance in coordinate system representations, arising or enforced by graphical presentations without geographic knowledge could lead to a misleading or even a false sense of actual topographic distance between objects. Training and experience remain factors with the fast learning of affordances to control for in future research. In developing this research, the distinction graphical and geographical, which becomes in some cases problematic due to information-based functional approaches to geospatial comprehension [14] offers a good foundation for continuing this research and refining it empirically to understand contributing factors and the specifics of visual biases that impact Tobler's first law of geography.

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