Cognition 116 (2010) 130–135

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Brief article

The Earth is flat when personally significant experiences with the sphericity of the Earth are absent

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ARTICLE INFO

Article history:
Received 23 November 2009
Revised 8 March 2010
Accepted 9 March 2010

Keywords:
Cognitive distances
Mental model
Flat earth
Physical
Heuristics
Cognitive maps
Spherical MDS
Radius
Estimation
Conceptual change
Cognitive development

ABSTRACT

Participants with personal and without personal experiences with the Earth as a sphere estimated large-scale distances between six cities located on different continents. Cognitive distances were submitted to a specific multidimensional scaling algorithm in the 3D Euclidean space with the constraint that all cities had to lie on the same sphere. A simulation was run that calculated respective 3D configurations of the city positions for a wide range of radii of the proposed sphere. People who had personally experienced the Earth as a sphere, at least once in their lifetime, showed a clear optimal solution of the multidimensional scaling (MDS) routine with a mean radius deviating only 8% from the actual radius of the Earth. In contrast, the calculated configurations for people without any personal experience with the Earth as a sphere were compatible with a cognitive concept of a flat Earth.

1. Introduction

It was a long and difficult journey for humankind to prove, accept and establish the concept of a spherical Earth. As long as humans were not able to explore the Earth from a non-geocentric perspective, they had to estimate the radius of this spheroid on basis of typical phenomena associated with a spheroid. Around 240 BC, Eratosthenes of Cyrene, for instance, integrated the knowledge of the distance between the cities of Syene and Alexandria with the different angles of elevation of the sun at these places. The outcome of this simple trigonometric calculation was a remarkably accurate estimation of the Earth's radius with a deviation of <1% (Dutka, 1993).

Besides these classic findings later validated by modern science, the spherical nature of the Earth is also visible to the naked eye. In his book *On the Heavens*, Aristotle already called attention to certain arguments favoring a spherical Earth. He described, for instance, the phenomenon of the circular shadow of the Earth on the moon during the lunar eclipse which is observable at all elevations of the moon—an effect that cannot emerge from a shadow cast by a round disc but only by a spheroid (Kuhn, 1957). Other directly visible phenomena are, inter alia, that objects traveling towards the horizon are increasingly covered from the bottom to the top until their full invisibility, or the simple fact that the horizon is slightly bent.

Today, there is neither a rational debate nor fruitful discussion on the pros and cons of the concept of the Earth as a sphere—it is a scientific truth in the physical sciences. But what about the cognitive model of the Earth? Do people really use the concept of a spherical Earth in everyday life? When we explicitly asked undergraduates ($n = 120$), none of them believed in a flat world. It is well known that explicit, forced-choice questioning produces an increase

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doi:10.1016/j.cognition.2010.03.009

of scientifically correct responses and the report of more internal consistent models (Vosniadou, Skopeliti, & Ikospentaki, 2004). This could be explained by the fact that people tend to simply retrieve explicitly learnt knowledge in such situations. Thus, this way of asking only validates the high degree of common-sense regarding this issue, but does not provide any insights into the deeper cognitive representation of the Earth.

Cognitive research has invested much effort to obtain cognitive representations of geographical relations, which are known as "cognitive maps" (Tolman, 1948). Such cognitive maps can be interpreted as the cognitive representation of a geographic map containing systematic as well as fluctuating cognitive distortions. Cognitive maps can be retrieved directly by map reproductions (e.g., Hirtle & Jonides, 1985). Yet, this has the practical limitation of participants' drawing abilities and the cognitive limitation that participants might not be able to construct a coherent map from scratch. Indirect retrieval of cognitive maps are much more cognitively impenetrable. They can be realized by estimation of directions (e.g., Glicksohn, 1994), estimations of alignments relative to adjacent geographical units (Friedman & Brown, 2000), or the measurement of cognitive distances (Montello, 1991).

Montello (1991) defines cognitive distances as "mental representations of large-scale environmental distances that cannot be perceived from a single vantage point" (p. 101). This definition reveals the fundamental problem of cognitive distances. Given that they cannot be seen fully from one point at one time, people have to estimate large-scale distances using different heuristics. For instance, distortions arise from hierarchical structures of cities, areas or continents: people tend to overestimate the location of hierarchically higher-ordered elements to the disadvantage of nested elements: for instance, Chicago and Rome are at the same latitude (42°N), although Chicago is cognitively located much more north of Rome (Tversky, 1981) due to at least two heuristics: (a) Chicago is located in the north of the USA and Rome is located in the south of Europe; as the USA and Europe are thought to be approximately aligned on the same area of latitudes, Chicago is dislocated north of Rome; (b) Chicago has hard winters and is located near Canada, a country known for its cold climate; Rome is a sunny and hot city, not very far from Africa, a continent associated with deserts and a hot climate; the general heuristic for climates suggests: cold means north, hot means south; consequently, Chicago must be north of Rome. While the general distortive nature of cognitive maps was found to be relatively impenetrable by expertise (Friedman & Montello, 2006), research in the domain of social cognition shows strong overlaying effects of social attitude. Carbon and colleagues showed that negative attitudes, for instance towards the German reunification (Carbon, 2007; Carbon & Leder, 2005) or towards the war in Iraq (Carbon, 2010) systematically change the cognitive distances between places like the Western and the Eastern part of Germany or Europe and the USA, respectively. Although systematic as well as unsystematic cognitive distortions are observable, humans are able to estimate areas (e.g., Battersby & Montello, 2009; Brown & Siegler, 1993) or distances (e.g., Carbon, 2007) impressively well. This is documented by high correlations between estimated and actual measures of .82 up to .93 in the given studies, qualifying such estimations as a relatively valid measurement.

2. The current study

To investigate the cognitive representation of the Earth, the current study made use of an indirect method, i.e., distance estimations (cognitive distances). To be able to measure deviations from a flat vs. a spherical concept of the Earth, we asked our participants to estimate large-scale distances between different cities all over the world and submitted these distances to a specific spherical multidimensional analysis with variations in radius.

2.1. Methods

2.1.1. Participants

Forty-four participants ($M = 26.9$ years, range: 19–71; 33 female) took part on a voluntary basis. All were naïve to the purpose of the study and none of them had specific expertise or training in geography or astronomy; additionally, when asked explicitly, none of them believed in a flat world. As explained in the *Results* section, the sample was split in two groups, one including people who had personal experience with the Earth as a sphere, the other including people who had none of such personal experiences.

2.2.2. Design and procedure

The study consisted of two parts: (1) Estimation of all possible distances between six cities situated on different continents: Berlin (Europe), Cape Town (Africa), Los Angeles (North America), Rio de Janeiro (South America), Sydney (Australia) and Tokyo (Asia). The 15 distance estimations (see Fig. 1) were randomized across participants and had to be estimated in kilometers. (2) After completion of the estimation task we asked the participants a series of questions regarding their traveling experience, geographical and topographical knowledge, self-assessments of their knowledge and the diameter of the Earth, in order to gain insight into predictors for different cognitive representation of the Earth. We also asked whether they could "honestly" imagine the Earth travelling around the sun and the Earth as a sphere. The last task for the participants was to answer the question whether they had ever personally experienced the Earth as a sphere; if so, they were asked to describe this situation in detail. All items asked are listed in Table 1. The testing was conducted individually and took less than 20 min per participant.

2.2. Results and discussion

The estimated (=cognitive) distances were submitted to a multidimensional scaling to obtain a configuration of the cities that showed the least disparities between the actual physical distances and the estimated ones. To estimate the cognitive radius of the Earth, we employed a special multidimensional scaling algorithm in the Euclidean 3D space