Cognitive Geography. Space Reflected in the Mind

Adriana Galvani, Margarita Zaleshina, and Alexander Zaleshin

Abstract Modern science has already reached such a high level that technological solutions in practice expand the limits of the capabilities of human intelligence and move forward in the creation of artificial intelligence (AI). The topic of automated decision-making in navigation is constantly being included in global research and is funded by several state and commercial institutions. Investigating the ability of the brain to orient spatially is very important because, in the future, AI will require not only the usage of typical template solutions for orientation, but also the ability to handle fuzzy spatial information. Hidden geographic objects can be defined as those objects that are not explicitly recognized, but at the same time, they are perceived as sensory stimuli and actively processed and integrated into the brain. Based on only part of an incomplete object, the brain itself is able to think of its continuation, and this helps in finding the way and in remembering the way. However, people increasingly cognize and represent the Earth through devices, while humanity is losing the innate ability to perceive the environment, which is present in the animal world. Animals have a multicomponent sensory contact with natural elements, they form their own mental maps based on orientation by the Sun, by stars, by the surrounding landscape, i.e. by the same natural landmarks that people followed in ancient times. Even the ancient Mayans and Aztecs were more able to perceive spatial knowledge on different scales than many modern users of new electronic devices. Presently it is important to understand how the mind perceives, draws and creates a picture of the surrounding space in memory. Using cognitive descriptions in geography, it will be possible to integrate algorithms of innate spatial perception with numerous technological applications, expanding the use of AI for complex spatial tasks.

A. Galvani (✉)
University of Bologna, Bologna, Italy
e-mail: adriana.galvani@unibo.it

M. Zaleshina · A. Zaleshin
Moscow Institute of Physics and Technology, Moscow, Russia
e-mail: terbiosorg@gmail.com

A. Zaleshin
e-mail: alex.ihna@yandex.ru

M. Krevs (ed.), *Hidden Geographies*, Key Challenges in Geography,
https://doi.org/10.1007/978-3-030-74590-5_2

Keywords Cognitive geography · Mental maps · Brain · Spatial perception · Ethology

1 Introduction

In this paper, we propose a holistic consideration of the cognitive problems of geography, considering the importance of both the macrocosm—at the level of animals' spatial behaviour and space exploration by humans, and the microcosm—at the level of mental perception and neural networks.

Modern global communication networks are extremely heaped and reach out to the inhabitants of the entire planet; but sets and methods of communication in a single brain can be more sophisticated, more effective, and more complex. Researchers still don't understand the real potentialities of the human brain, if not in trans-disciplinary teams, although both the EU and the US are funding many kinds of research and development in this field. The world's largest companies—for example, Google—are investing heavily in improving their natural and artificial intelligence. But all face the difficult challenges of an unexplored world, since every human brain is a mystery even to its owner.

Nowadays, the rapid development of medical and scientific technology—such as electroencephalography, functional magnetic resonance imaging, computed tomography and optogenetics—allows researchers to better study the structure of the brain. Therefore, it became possible to examine the basis of human behaviour at the level of brain structures.

In addition, the rapid development of geographic information technologies allows to increase the volume of big data processing on spatial objects and to increase the accuracy of tracking movements using global navigation satellite systems (GPS, GLONASS, and Galileo).

We believe that the study of human activity using geoinformation systems can help in decoding neural network structures, and vice versa, the explanation of the principles of the origin and propagation of neural activity can help in the development of better ways to interact with the Earth's space.

2 Mental Perception of Spatial Data

Alessandro Galvani, a physicist at the University of Trento, has explained in simple terms the complexity of creation: "All the creatures derive from the decay of stars; when they, at the end of their life, are falling off, the elements which are composed of, don't dissolve, but they congregate under other forms, all the forms of the universe" (unpublished quote).

Similar concept is affirmed in philosophy by Gregory Bateson (Fairlamb and Bateson 1979; Turner and Bateson 1980; Bateson 1999), who investigated the unity and relationship of man and nature. In addition, Bateson applied principles of cybernetics to the field of ecological anthropology and the concept of homeostasis. He wrote: “People live in space, and space forms their bodies and minds. Starting from the world around us, we need the help of geography—which the only real explanation of what occurs to us derives from. In conclusion, we can say that we will start from geography to know ourselves” (1999: 171). Perhaps the space that is more worth exploring is not the space outside, but the space inside, or something embedded in our mind and about which we know very little.

Geography of the outside world exists, but is there a geography of the inside? How is geography mentally understood? Does the spatial structure of neural networks affect cognition? Is it possible to combine these three geographies (external, mental and neural)? How can they interact?

Environmental cognition, together with the use or management of the territory, gives meaning to the history of people and models their consciousness and culture.

Modern anthropology no longer takes into consideration man solely in his human condition, but the whole human being in its destiny and vocation.

Geography comprehends not only the physical features on Earth, but even immaterial aspects of mind, and some technologies of psychology and psychiatry could be applied on it. Main topics of geographies of the mind were shown in (James et al. 1976).

The purely physical base of space expands human possibilities of observation, which inflate the reactions that trigger brain connections and consequently intellectual abilities.

The spatial analysis is associated with the mind which organizes the observations and the connections; the analysis is able to modulate new perceptions into different organizations. The connections identified in space are easy to infer: spatial elements are perceived in a global or assembled way, the perception itself selects connections through a process that takes place first in the space, then in the brain. This process was named by Claude Bernard (French physician and physiologist, 1813–1878) as *intérieur-terrain* which replaced the term life forces that are creating self-regulation in the nervous system. These findings are considered an antecedent of the contemporary cognitive science.

The brain is in fact continually connecting the internal and external contexts: there is the external space, the brain observes it, the brain interprets it; describes it; interiorizes it, and finally uses and modifies it.

There are, according to the modern neurological studies, internal mechanisms of interpretation of space which make it different, depending on its perceptions and uses. The connection between space and mind has not yet been entirely explored, but the space of the mind is broader than the outside space, and it is more flexible, more blended—one could say that in the mind there are more landscapes than in reality.

The individual and his environment are a dynamic configuration in its totality; all the parts are closely interrelated and continually interchanging, and under such constant interaction it is very difficult to say where a line of demarcation could be drawn (Linton 1945).

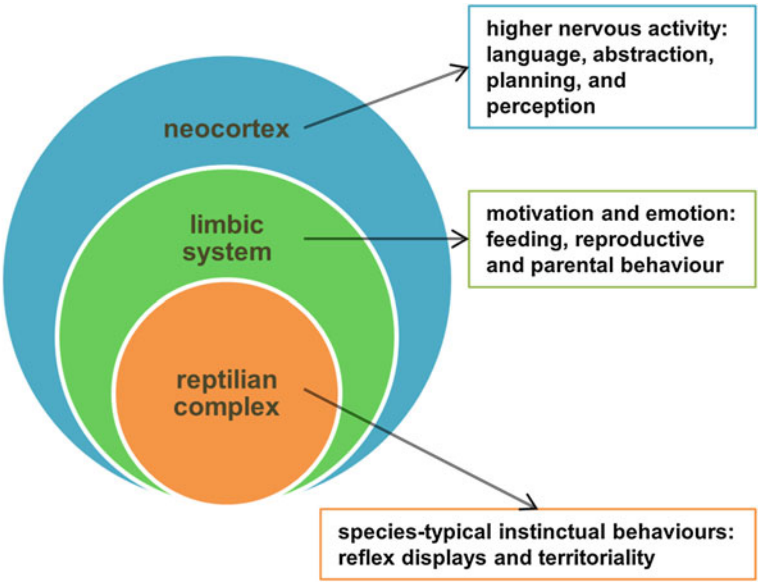

Fig. 1 Paul McLean's Triune Brain model

As demonstrated by scientists, human and animal brains maintain memory of all past knowledge (naturally hidden in the subconscious) of millions of Earth's lives, especially correlated to natural world features. Such example are animal migrations, following always the same paths, guided by natural characteristics, like Sun and stars (Berthold 1991, 2003).

Philosophy calls this "innatism", which can be explained through the "three brains theory", or the "Triune Brain Concept" (McLean 1990) (Fig. 1).

"The division of the brain into three parts constitutes what MacLean calls the Triune Brain of mammals (meaning one evolved brain could entail three brains, from an evolutionary perspective). The three stages of functioning are related in a way that the most recent one evolved into a neo-mammalian neocortex of the cerebral hemispheres, which surrounds the older paleo-mammalian limbic system, which, in turn, surrounds the ancient reptilian upper brainstem" (Gould 2002).

According to this concept, we are what we have learned and what is hidden in the core of our heads. The last goal could be to restore the innate skills and combine them with new technical instruments—an orchestra of three brains, playing in different ways. Special education could merge the knowledge of the natural world with new technological abilities.

This could be confirmed with the example of birds, which are among the oldest living species. Surely, they are the most capable of organizing their scheduled trips along thousands of kilometres, even if other species are more mobile. They use innate capacities related to Earth's movements, or solar and stars' relative positions. Some of these capacities are also present in human ancestral mobility, as demonstrated by Bedouins and by the skilled navigators during the time of the great oceanic discoveries.

Researchers suppose that birds can use mental maps in their flights (Golledge et al. 1996; Montello and Freundschuh 2004). As a result, birds follow the same way year after year in wintering season, searching for a better climate and richness of food. The reason is always food, even for humans, who have been migrating since their first appearance on Earth.

A theory of cognitive mapping has developed that depends only on accepted properties of hippocampal function, namely, long-term potentiation, the place cell phenomenon, and the associative or recurrent connections made among pyramidal cells. It is also possible that the cognitive mapping functions of the hippocampus are carried out by parallel graph searching algorithms implemented as neural processes (Eckardt 1980).

Surely, animals maintain those natural capacities; people, on the other hand, have already translated natural abilities into technical functions, attaining the excellence of GPS and GIS maps elaboration (www.esri.com). Modern behavioural geographers have started working with perception and are already using mental maps to study the visualization of cities and the spatial preferences of travellers. In the era of smartphones and global Internet coverage, applications such as ArcGIS Online (https://www.arcgis.com/index.html) or CartoDB (https://carto.com) allow users to use the technology online (Pánek 2016).

3 Spatial Orientation in Humans and Animals

The mystery of birds is hidden in prehistoric times millions of years ago, in the pre-humanoid era, considering that birds are among the oldest creatures. Their brain structure is sculptured in a way that they do not need to learn migrating habits from elders. It has been discovered that young birds, which never had the opportunity to follow adults on their trips, are able to find the same ancestral path, going away and coming back.

What is also strange is that even caged birds are feeling the urge to migrate at the same time as free birds. Scientists captured animals to release them away from the usual track of the species. Once released, animals retrieved the usual track and resumed the desired trip.

They fly thousands of kilometres, spending lots of energy and fighting against natural elements, risks and predators. In the eighteenth century, scholars assumed that birds do have a special endowment—not gene, since it was not discovered at that time—but a specific hormone of movement. Later, scientists had supposed that birds have specific skills in perceiving sunlight, following stars or magnetic poles, and finding natural direction which satisfy their needs.

The influence of natural landscape on spatial perception and, consequently, on the trajectory of movement was shown in our previous study (Zaleshina et.al. 2019).

Multiscale brain and space interactions are shown in Fig. 2.

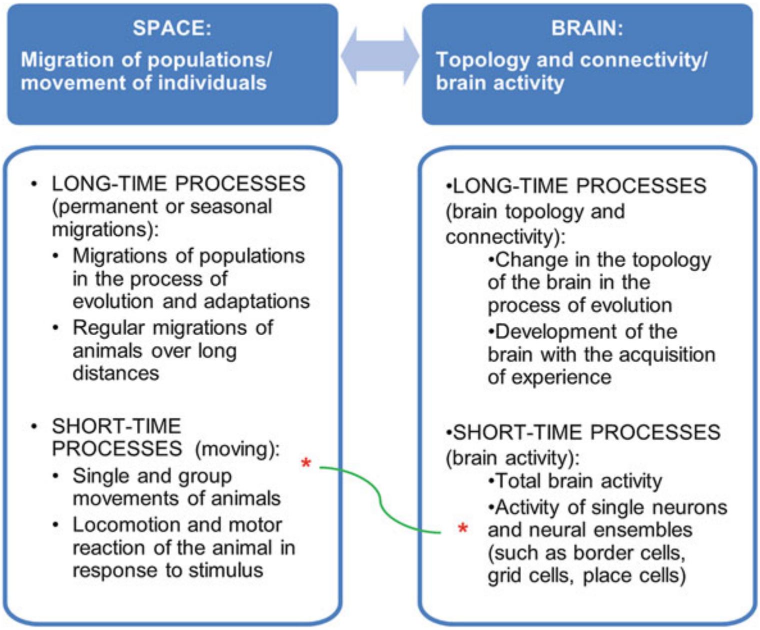

Fig. 2 Multiscale brain and space interactions

Bedouins can also travel through deserts for long distances. Civilization and urban habits such as motorization and economic changes have rendered Bedouins sedentary, so they do not follow any more directions according to the natural elements.

Modern way of life is changing human habits. We can presume that all humans have had the same abilities, remembering the hominids who reached Europe and Asia from Africa. The dispersal from Africa has been a long-lasting event, so long that it continues until now. It has permitted the survival of the best species and the disappearance of frail species. Hominids didn't have any instrumentation, so we can presume they followed their instinct, supported by the natural perception of temperatures, winds' direction, and Sun's and stars' position. History tells about the exceptional abilities of pre-Amerinds such as Incas, Mayan or Aztecs, not only to perceive, but also to measure natural phenomena. The point to which they arrived in mathematical and astronomical measures was so elevated that not only we are unable to repeat them, but even unable to understand them. They predicted natural events for millennia ahead and they understood astronomical phenomena which we can only interpret today with sophisticated instruments.

The principles of topological psychology were built as a set of constructive concepts based on experimental investigations as well as real psychological cases (Lewin 1936). Our attachment to Earth remains in our constant sense of nostalgia for something to be found elsewhere, or for our birthplace. Migrants try to return home. When we feel unsatisfied, we try to change life or, often, to change our place of living. No one is, probably, satisfied with what they have, or the place where they live. Everyone has the feeling of something that exists somewhere else, which could fulfil their lives in the best way possible. Surely, the sense of dissatisfaction with routine life, or the sense of going, like some migrant birds or nomads feel, is inexplicable. Birds are the ancestors of humans; they know where to go, unlike men who do not know where to go; they only feel to go *somewhere*. This sense of otherness can instil an illness of unrest.

The scheme of spatial perception in animal movements is shown in Fig. 3.

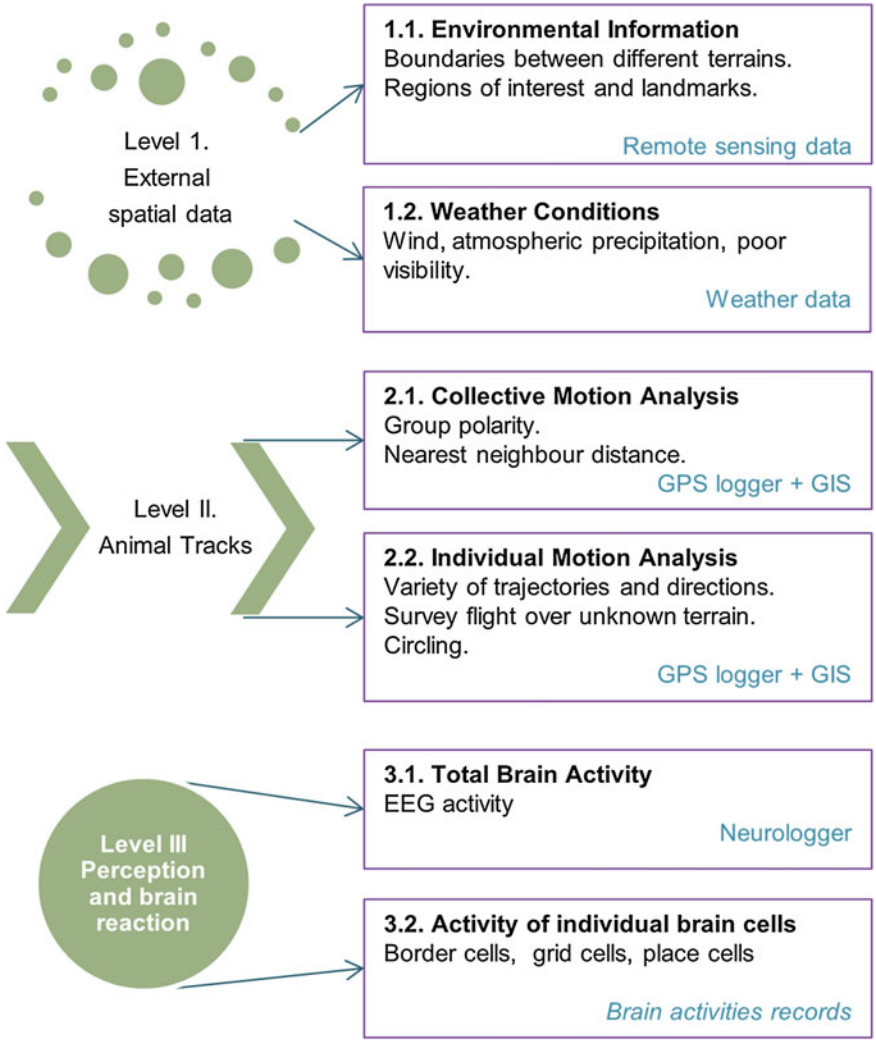

Fig. 3 Spatial perception in animal movements

Animal models bring important solutions for human psychiatric studies, for example, to help to determine the generality of emotion and personality, establishing that they are not only humans. Human interest in animal behaviour deeply extends researches into our common evolutionary roots. There are some kinds of similarities between wolves and humans in the behaviour of social interaction. It is evident that humans are afraid of wolves, but also that the latter are afraid of humans. Wolves illustrate how some actions which may be categorized as more instinctive, and others, which are considered to be more learned—on the continuum that ethologists define as ranging from fixed reflex to flexible intelligence—have been retained in the ancestral part of the genome. Much learning in wolves occurs because of social transmission and remains a question for future inquiry.

At the third level of analysis, of the physical ecosystem, wolf populations are influenced by biotic (e.g. prey, competing species, diseases) and abiotic factors (e.g. winter severity, fire cycles, drought cycles). From a theoretical perspective, each of these systems is viewed as subjective because individuals harmonize within groups, subpopulations and ecosystems. Surely, the effects revealed by experiments on wolves could be reproduced on several other animals, especially migrating animals. Unfortunately, at the time when technological processes facilitate new skills, we are losing some abilities. In humans, there is a sort of balance between learned skills and innate skills which become progressively unknown. Questions of animal awareness and evolutionary continuity of mental experience were shown in (Friedman and Griffin 1977).

Discoveries of Columbus, Vasco da Gama and other great navigators were surely related not only to commercial expansion, but probably unconsciously, also to the sense of understanding where our world starts and finishes, as far as our dreams can bring us.

One thing is to take part in events, the other to see them on television; one thing to be among people, another to speak on a smartphone; one thing is to go on a virtual vacation to the Maldives or Hawaii by opening YouTube, another to travel to China like Marco Polo, or going to Antarctica and feel the freezing like Amundsen. Bedouins and nomads were able to make long trips following the horizon without instruments. This was undoubtedly a capacity which belonged to all hominids in prehistoric times.

Understanding animal behaviour is key to our survival, especially behavioural genetics which is a rapidly expanding area in the study of animal adaptivity (Jeong and Di Rienzo 2014). Answers to questions about how behavioural dissimilarity is related to the interaction of genetic variation and environmental variation are still elusive (Packard 2019).

4 Positioning Systems in the Brain

In 2014, Edward and May-Britt Moser, and O'Keefe won the Nobel prize for medicine and physiology for their studies on the positioning system in the animal brain. Moser's discoveries, made at Trondheim University in Norway, confirm that the animal brain can store a lot of information on spatial organization: during space exploration by mice, pathways in form of grids are permanently stored into mental patterns, so that animals can restore previous experiences and retrace an already made way (Leutgeb et al. 2005).

Such information is stored in space cells and organized into grids cells.

All this has been found out on mice and it is supposed to exist also in humans, on whom the experiments are more challenging. It is certainly obvious to suppose that the same capacities are present even in humans, since many animal species do have a spatial memory inherited from ancestral times, even from the first appearance of those species on Earth.

The results of many years of research are the discovery of place cells, and later, grid cells on brain, or further, border cells.

The discovery derives from studies on mice. Researchers put electrodes on the heads of rats along their way on the search for food. The first time, the animals start searching their way to food, they navigate without a sure direction, but when they repeat the same path, they learn the correct direction, and neural activities at a specific place mark the right path. The fascinating result of research is not only that animals are able to find the shorter way to the final goal, but also that the neuronal activities appear at specific points which correspond to the nodes of triangles whose composition forms hexagons. Place cells become grid cells.

Scientists let us suppose that even the human brain has such potentialities and performing activities. Geometrical precision is the first passage from terrain to maps, assuming the methodology of the first measures of territories for governmental purposes. Same schemes are found and revealed through electrical connections on caged mice, recorded when they are in search of food.

From that, it could be argued that the brain functions like a GPS, and that it can create maps.

One would suppose that it is very easy for us to read maps, but there is a great gap between having a direction capacity in the brain and reading maps created by technicians. This is the gap which exists between instinct and science, from which we must learn at school how to read and create maps.

Without a doubt, animals follow only instinct, whereas people do not maintain any trust on instinct, and only trust science. However, relying on science, we little by little lose our instinctual abilities.

5 Digitalization of the Mental Representation of Spatial Relationships

The process of digitizing maps represents a cultural revolution as decisive as the language. Design principles for presenting spatial information should bear similarities across these domains but also be somewhat specific to each one (Taylor, Brunyé and Taylor 2008). External visuospatial representations have to bear many similarities to those that reside in the mind (Tversky 2005).

It corresponds to the transformation of spoken language into written language that has changed civilization forever. The social evolution of language and human relations have many correspondences in human movements. To find the links between modern styles and ancestral behaviour requires intercultural studies, which implies scientific, technical and humanistic fundaments of knowledge.

New instruments could advance better if scientists coordinated biological research with medical, engineering and geographical research. The connections which constantly occur on Earth are materially reflecting the hidden performances of the nerve cells, which are interlaced through electrical stimulations.

One such opportunity is the research on Artificial Intelligence (AI). This is possible through research on the brain, including the application of deep learning in neural networks (Fig. 4).

Synapses in brain are the highways for mental information's communication, resembling highways, streets and avenues that connect the elements of a place. The nervous net is a model of constantly interchanging communication, which mixes memory, sensations, emotions, desires, dreams, or forgotten past experiences. It is a complex system of virtual grids, like the net of material communication which we are drawing in several ways on Earth, with movements and human experiences. We can add the media nets, but these are considered to be material ones because they are made through electrical connections. They become virtual when they stimulate

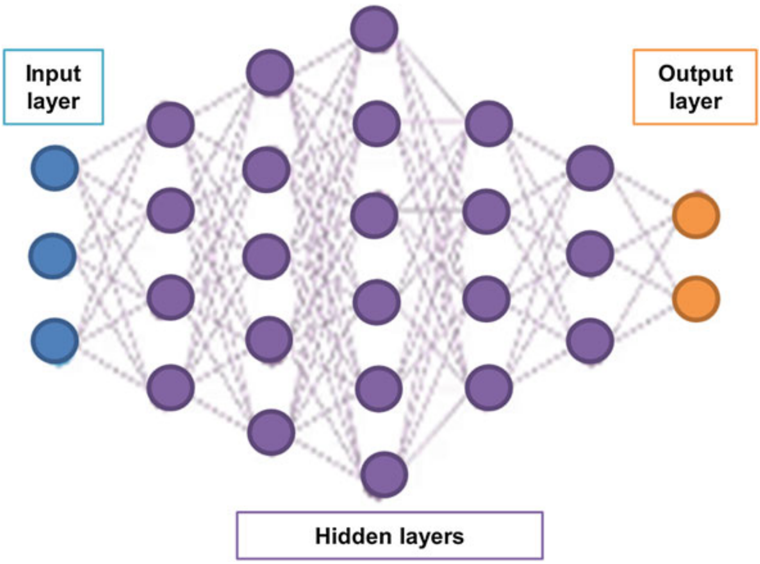

Fig. 4 Deep Neural Network. The network of highly interconnected layers—with input layer on the left, output layer on the right, and customizable hidden layers in the middle (*Source* https://www.esri.com/training)

ideas and reflections in people; only when they stimulate dialogues among people, they become real and material, even if intangible.

We could consider GIS a help in the efforts to augment the set of prospects of both human and artificial intelligence.

6 Conclusions

Body and mind are closely related, just as cognitive geography and brain are connected at another level. In essence, we never will put an end neither to the knowledge of the world nor to our brain. We must recognize that in the mind, there are many multiscale spaces at the same moment.

Exploring the world online/virtually gives us an incredible quantity of images, but they are stored in the brain in different ways, increased by the fourth—time—dimension, and the fifth—memory—dimension. Thus, we are constantly building many worlds, but we will never be satisfied. We are continually searching for other worlds and other existences. With the help of science, we move and do more, we have more goods, we ourselves have become more technically qualified, and we develop our societies. But at the same time, we are losing spontaneity, becoming more intelligent with artificial devices and less intelligent without them.

With the progress of civilization, our contact with the natural world has gradually decreased, as has our sense of involvement with natural biomes. At the same time, animals that are increasingly dependent on global anthropogenic influence continue to be subject to natural elements. Climate change also affects the existence of humans and animals; it is likely to change the usual bodily properties and familiar behaviour, and consequently, psychology.

A goal could be to merge both abilities to become lords of the universe, since people think they are superior to other species, but they are not. They are the only living species among millions of other living species, without supremacy. We are able to learn, as are animals, but we have a duty to enhance this capacity for the best life of all living creatures. And cognitive geography can provide new tools for this.

References

Bateson, G. 1999. *Steps to an ecology of mind*. University of Chicago Press. https://doi.org/10.7208/chicago/9780226924601.001.0001

Berthold, P. 1991. Genetic control of migratory behaviour in birds. *Trends in Ecology & Evolution* 6 (8): 254–257. https://doi.org/10.1016/0169-5347(91)90072-6.

Berthold, P. 2003. Genetic basis and evolutionary aspects of bird migration. *Advances in the Study of Behavior*. https://doi.org/10.1016/S0065-3454(03)33004-9.

Eckardt, M.J. 1980. The hippocampus as a cognitive map. *The Journal of Nervous and Mental Disease* 168 (3): 191–192. https://doi.org/10.1097/00005053-198003000-00018.

Fairlamb, H.L., and G. Bateson. 1979. Mind and nature: A necessary unity. *MLN* 94 (5): 1218. https://doi.org/10.2307/2906578.

Friedman, H., and D.R. Griffin. 1977. The question of animal awareness. Evolutionary continuity of mental experience. *The Journal of Wildlife Management* 41(2): 332. doi: https://doi.org/10.2307/3800619.

Golledge, R.G., R.L. Klatzky, and J.M. Loomis. 1996. *The construction of cognitive maps*. doi: https://doi.org/10.1007/978-0-585-33485-1.

Gould, S.J. 2002. The structure of evolutionary theory. *Harvard University Press*. https://doi.org/10.2307/j.ctvjsf433.

James, P.E., D. Lowenthal, and M.J. Bowden. 1976. Geographies of the mind: essays in historical geosophy in honor of John Kirtland Wright. *Geographical Review* 66 (4): 497. https://doi.org/10.2307/213673.

Jeong, C., and A. Di Rienzo. 2014. Adaptations to local environments in modern human populations. *Current Opinion in Genetics and Development*. https://doi.org/10.1016/j.gde.2014.06.011.

Leutgeb, S., et al. 2005. Place cells, spatial maps and the population code for memory. *Current Opinion in Neurobiology*. https://doi.org/10.1016/j.conb.2005.10.002.

Lewin, K. 1936. *Principles of topological psychology*. New York: McGraw-Hill. https://doi.org/10.1037/10019-000.

Linton, R. 1945. The cultural background of personality. *Appleton-Century* 54.

McLean, P. 1990. The triune brain in evolution. *The Triune Brain in Evolution.*

Montello, D., and S. Freundschuh. 2004. Cognition of geographic information. *A Research Agenda for Geographic Information Science*. https://doi.org/10.1201/9781420038330.ch3.

Packard, J.M. 2019. Wolves. *Encyclopedia of Animal Behavior. Elsevier*. https://doi.org/10.1016/B978-0-12-809633-8.90078-5.

Pánek, J. 2016. From mental maps to geoparticipation. *Cartographic Journal*. https://doi.org/10.1080/00087041.2016.1243862.

Taylor, H.A., T.T. Brunyé, and S.T. Taylor. 2008. Spatial mental representation: implications for navigation system design. *Reviews of Human Factors and Ergonomics* 4 (1): 1–40. https://doi.org/10.1518/155723408X342835.

Turner, B., and G. Bateson. 1980. Mind and nature. *Rain* 36: 11. https://doi.org/10.2307/3032188.

Tversky, B. 2005. Functional significance of visuospatial representations. In *The Cambridge handbook of visuospatial thinking*, 1–34. Cambridge University Press. doi: https://doi.org/10.1017/CBO9780511610448.002.

Zaleshina, M., A. Zaleshin, and A. Galvani. 2019. Navigational strategies in transition from initial route. In *Geospatial Challenges in the 21st Century*, eds. Koutsopoulos, K., de Miguel González, R., and K. Donert, 335–353. Cham: Springer International Publishing. doi: https://doi.org/10.1007/978-3-030-04750-4_17.