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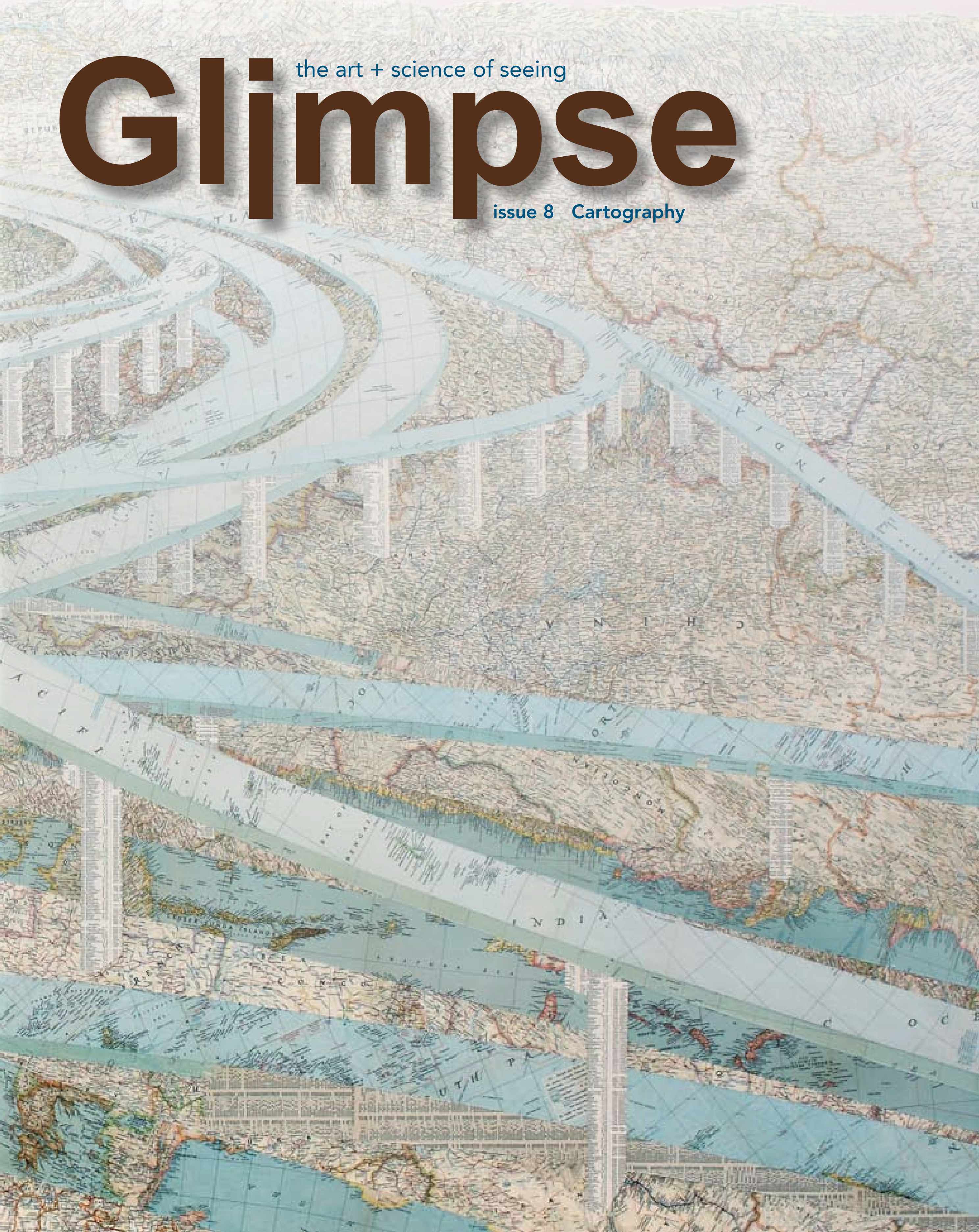
issue 8 Cartography



# C O N T E N T S

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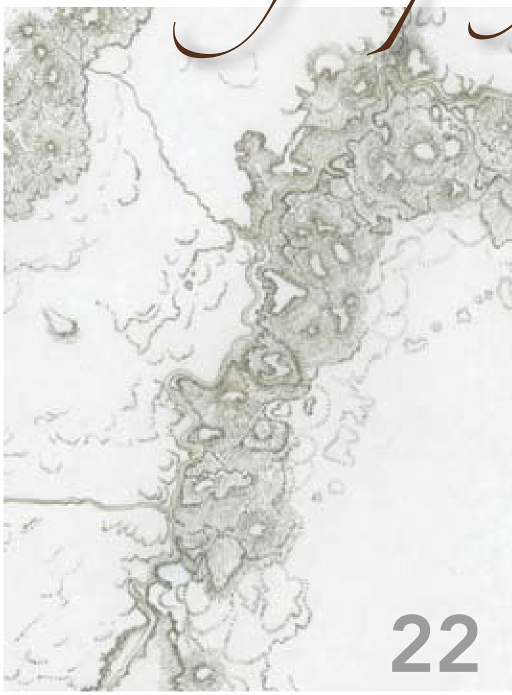


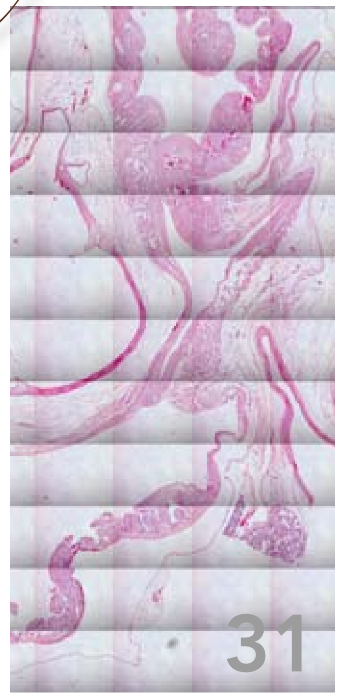


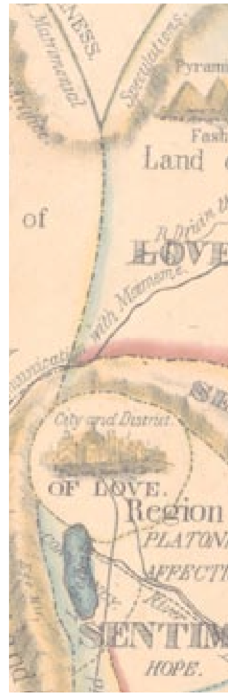


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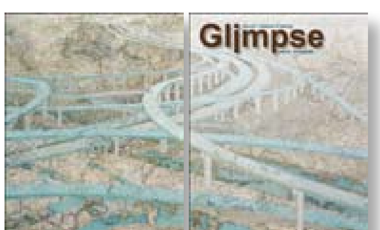



**(front and back covers)**
*Many Rivers*, 2009
Inlaid maps, acrylic, on panel
48 x 78 inches

# LOSING AND FINDING OUR WAY >>>

## A CONVERSATION ABOUT COGNITIVE MAPPING AND ORIENTATION WITH NEUROSCIENTIST GIUSEPPE IARIA

***by Rachel Sapin with introduction by Carolyn Arcabascio***

**A trip to the bank, a grocery run, a quick stop at the post office. For most of us, the journey to such routine destinations is so familiar and second-nature that the experience is an entirely forgettable one. But for some, the distressing time spent *en route* is as noteworthy an event as anything that may happen upon arrival. These otherwise capable people get lost along the same route they've been traversing every day for years; landmarks, lefts and rights don't help. But regardless of the mundane or stressful nature of one's daily travels, the brain is always to blame or to thank. And according to neuroscientist Giuseppe Iaria, cognitive mapping and connectivity are key. Dr. Iaria talks with *GLIMPSE*'s Rachel Sapin about the neural mechanisms that help those of us who succeed in "getting there," or that fail those of us who don't.**

**Rachel Sapin (RS):** *Could you first explain how it is that we are able to navigate at all? Is a sense of direction innate or learned in people without perceptual impairments?*

**Dr. Giuseppe Iaria (GI):** The ability to orient and navigate in space is a very complex phenomenon in humans and non-human animals because it involves many different cognitive functions: perception, attention, memory, decision-making, mental imagery and so on. When people talk about topographical orientation, it's not easy to define it in terms of cognitive skills. What *is* easy to say is [that topographical orientation is] basically our ability to find our way around our environments. [Some] people may find ways of [learning a pathway] or getting from A to B by using left and right body turns or distances. Others may remember the same pathway by associating body turns with specific landmarks: they have to turn left at the bakery; right at the cinema; right at the bank again, and so on. Others may just follow sequences of displacement, and others, with time and practice, may actually use mental representations of the environment.

So, whenever the environment becomes familiar, you have in your mind a mental map that you use in order to get from place to place. Now, if you think about those cognitive functions—memory, attention, perception, decision-making skills, mental imaging—you realize that these are functions that children develop over time. There are certain strategies that children actually use when they are four-, five-, six-years-old, and other strategies that they may use for orientation when they are older—eight-, nine- or ten-years-old. [We understand it as] developmental, but just because we don't have evidence in terms of genetics so

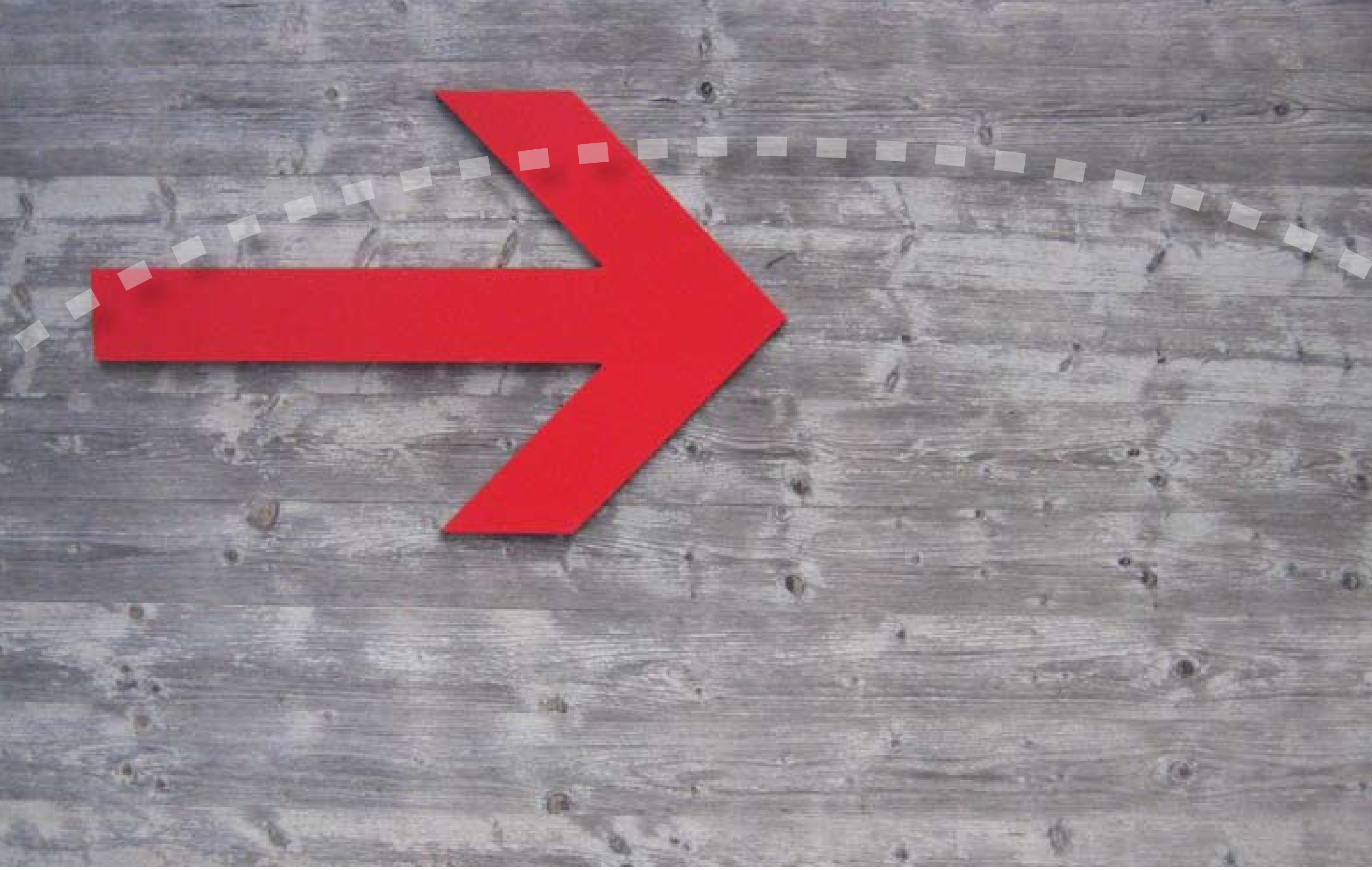


*"Disoriented yet?" Berlin, 2008. Photograph courtesy of flickr member dospaz.*

far. I say *so far* because we are doing a study trying to find out if there is a combination of genes that can identify some orientation skills in individuals. What makes this story complicated is that there is huge variability across individuals in cognitive strategies for orientation. There is also huge variability in terms of how good or bad people are in using certain strategies compared with others. Where you live also affects which kind of strategies you use.

**RS:** ***It sounds as if there isn't even a "normal" way to navigate an environment.***

**GI:** Exactly. It's very difficult to find out what is actually normal. My interest in this topic came out when I was trying to understand all this variability across individuals. I'm not talking about pathological cases, or people who have a disorder. I'm talking about normal people without any neurological or brain injury. I was trying to understand what was, at that time, the relationship between this variability and neuromechanisms. In the last few years, we have done a fair job in explaining [the way] some behavior affects variability. The literature [on the subject] explains that aging has an effect on orientation skills. We just published a manuscript in which we show that by age 45 orientation skills start to decline in the healthy populations. Among the variety of strategies that start to decline though, the ability to form a cognitive map is the skill that predicts best aging decline. The effects are expressed in terms of time required to form mental maps and errors made while using them, which reflect a decline in



*"Topography of Terror" Berlin, 2007. Photograph courtesy of flickr member Luis Villa del Campo.*



cognitive skills and therefore a decline in the neural mechanisms responsible for those skills. Gender also has an effect on orientation skills. We know that women probably have a bias in looking for landmarks and trying to make use of them; whereas men may actually rely on different kinds of information like body turns or distances. So we have some sort of variability that can be explained in terms of behavior, but we don't know so much more than that.

**RS:** ***To touch on another aspect of this, how much have technological advances in neuroimaging allowed you to begin to understand this very complex skill humans and animals have?***

**GI:** [These advances have been] huge because until around 15 years ago, neuroscientists relied mainly on clinical populations [to study humans]. We used to do experiments on healthy controls (human subjects), and we formed our hypotheses. Then we went looking for brain damaged patients; damage in certain regions will affect certain orientation strategies. A major criticism to this neuropsychological approach was that we investigated something that wasn't there anymore: there is damage in the brain, a *lack* of orientation skills. Another criticism was that one couldn't really make so much of a brain that is damaged because maybe it organizes in a different way. When the neuroimaging technique became available, we were able to finally describe how things worked in a healthy brain. In the first few years, people started using virtual environments—very simple kinds of video games—to design tasks that aimed to assess specific orientation strategies. You cannot do fMRI in real environments, so we tried to recreate the specific daily life activities in terms of orientation by using these virtual environments. We were able to show that the use of different orientation strategies relied, for example, on different brain regions as confirmed by neuropsychological status. This was the first approach in neuroimaging; it was purely functional. People were looking at functionality of the brain—increased neuroactivity in specific regions compared to others: *why* people were using different orientation strategies. In the last seven or eight years neuroimaging has developed much more technologically, and we are able now to make sense of structural data—very fine differences within the structures of the brain and specific brain regions—rather than the functionality of the brain alone. We have found in our lab that there is a very strong relationship between specific brain regions—how they are structurally organized—and the ability to make use of specific orientation strategies.

**…THEY GET LOST EVERY DAY IN THE MOST FAMILIAR SURROUNDINGS…**

**RS:** ***Topographical disorientation, which you've studied for a long time, has to do with a specific part of the brain being structured somewhat differently. Can you tell me what this condition is?***

**GI:** A little bit of clarification: We started this conversation by saying that topographical orientation is very complex because there are different functions involved—memory, perception, etc. Now, as you can easily realize, any damage in the brain that is going to affect one of these skills may affect your ability to orient. I'll go to extremes: if you have damage in the brain where you cannot recognize landmarks, then you get lost because you cannot recognize the bakery or the bank where you were supposed to turn left or right. If you have damage in the brain that is affecting your memory, generally speaking, then you get lost because you don't remember where things are. If you have more frontal damage, which is affecting your attentional skills, then you get lost because of this problem. People refer to these patients as having a topographical disorder. If you want to be more specific, these are *acquired* topographical disorders. They're acquired because the brain damage occurred *after* the person developed properly. That's the part of the story that I was interested in.

There is another part of the story, which is not actually a disorder; it's a condition called Developmental Topographical Disorientation. This distinction is very important. The people that I'm describing and investigating right now do not have an acquired topographical disorientation. There was no brain injury—no car accident, no brain tumor or stroke. They just didn't develop certain skills. We have found that these people who have this condition, in which basically they get lost every day in the most familiar surroundings, have been this way all their lives. That's the reason why we call it *developmental* and not congenital topographical disorientation; we don't have evidence that there is a gene that is actually going to develop or define our orientation skills. These people are basically people like you and me: no memory-related or perceptual complaints, no decision-making or mental imagery problems.

**RS:** ***Do you have any ideas as to the cause at this point in your research?***

**GI:** So people with what we call DTD [Developmental Topographical Disorientation] get lost in the place where they have lived for 20 or 25 years for the simple reason that they are not able to form in their minds a mental map of the environment. That's what we call the *cognitive map*. So, if you move to New York, you might move to a place that is 15 or 20 minutes walking-distance from your office. You will most likely look around for landmarks, trying to define the pathway to get to your office everyday; or you will Google your address—you will try to make sense of things. You will start having experiences with the environment, which will become more and more familiar with time. You will discover the area around you—where to find nice bread, and so on. With time, you will have a very good mental representation of the environment. People with DTD are not able to create this mental map. Whenever they move, they have to remember sequences of pathways, which is fine; but they cannot do this for every place they go because it will be too much for the memory. So if they don't have this map in their minds, whenever they move around, they don't know where things are, even if they have been there for 20 years.

WE DON'T HAVE EVIDENCE THAT THERE IS A GENE THAT IS ACTUALLY GOING TO DEVELOP OR DEFINE OUR ORIENTATION SKILLS.

There's one thing I want to add that is very important for us, which is where our research with these DTD people is taking us. We're doing a variety of things, but we have two major goals in our lab: one is to identify children who are not going to develop these important orientation skills. It's not because we don't care about these people, we absolutely do; but they have been this way all their lives. This means that my children or yours may not develop these important orientation skills. What we want to do is find out who these children will be.

We're doing several projects: one is developing a tool that will be able to assess a variety of orientation skills in schools; the other is to do genetic studies in families with members across generations. We want to identify genes able to detect this specific condition. Why all of this? Because it's easier to modify the development of children rather than modify the brain of a 55-year-old person. The other aspect we are really focusing on is the rehabilitation treatment for people that are not children. It's very important for us to use technology, but we also believe there is some cognitive rehabilitation that we can do. In some way, we are working on developing some sort of task that will help these people to develop those skills that for some reason they



*"bread and cakes": Bread and cakes in the shop window of Tunnocks Tea Rooms on Uddingston High Street, Glasgow, Scotland, 2010. Photograph courtesy of flickr member zoetnet.*

didn't develop when they were at a certain age. This is very important research for us and we're also using technology. For example, right now I have two German students in my lab who have designed a special belt that contains a compass, which gives you sensory stimulation wherever the north is. So you receive the vibration on your skin while you're wearing this belt, and if you wear it for six or eight weeks, our hypothesis is that we'll detect a change in behavior or performance in terms of orientation, but also a change in terms of brain regions, and connectivity between regions. If this belt has an effect on the neuroplasticity and reorganization of the human brain according to this new sensory stimulation, it will be a huge help for these people with topographical disorientation.

**RS:** ***Is creating a cognitive map—however you do that—essential to orienting ourselves?***

**GI:** It is absolutely essential. These people that I'm describing are the evidence. A very important question that I hope my lab will be able to answer in the next few years is: "What is a cognitive map? How do you build it?" I can tell you a definition of a cognitive map, which is "a mental representation of the environment in which the spatial relationships

*"Disoriented No 2," 2008. Photo courtesy of flickr member Owen Byrne.*





between landmarks are reported." It's not so much important to have landmarks on the map, but what is really important is to have proper spatial relationships between landmarks. Now, do we really have a [mental] top-view survey of the environment? If so, how do we create it? It's very complicated because if I ask you to imagine where the closest washroom is from where you are now, you can probably imagine how to get there through the walls. But if I ask you where Rome is compared to Paris, you would probably picture a top-view of Europe. The way that we represent the environment is different according to the space that we have to rely on, which probably suggests that it's also different in terms of acquisition of information. We can acquire the same cognitive map by using different kinds of information and this, I think, taps into the variability that we were talking about earlier.

There is no evidence in the scientific literature of how we create different cognitive maps, but we want to learn that. Some people may actually rely on very specific landmarks; some can actually build cognitive maps by relying on body turns and an outline of the environment. Some use verbal information. Semantic knowledge goes into the map as well. So if you meet your boyfriend in a nice bar and it's the first time you're meeting after a few months in Manhattan, then that bar will have a significance for you, which is different from the significance of a bar where you meet your usual colleagues every Friday afternoon. So how people use information to create a cognitive map becomes very, very complicated.

**RS:** ***The next thing I'd like to get into is the role of the hippocampus.***

**GI:** Everything that we reliably knew until about 20 years ago in terms of the hippocampus and orientation really comes from studies in rodents—rats basically. O'Keefe and Nadel are the two people scientists think of when they think about the hippocampus and spatial orientation. In 1978 they discovered via electrophysiological evidence that within the hippocampus in rats, there are specific cells called "place" cells that fire when the animals are in a specific location within the environment.[1] So you have cells that respond when the animal is in X, Y and Z location, and then other cells that respond when the animal is in a different location. [Athough] the first thoughts [on this matter were] from Edward Tolman, a scientist who started talking about cognitive mapping in 1948, O'Keefe and Nadel provided evidence [through their experiments] that if there are these cells, these neurons within the hippocampus that fire and respond in specific locations, it basically means that the hippocampus is in some way responsible for mapping the environment. Since these "place" cells were discovered, there have been many studies in rodents trying to prove when these neurons respond. What has been found is that they respond when animals are trying to map the environment, but relying on visual landmarks to do so. So this was translated in the human research in terms of topographic orientation soon after, in neuropsychological patients, and also in neuroimaging. The idea is that, even in humans, if the hippocampus is damaged, it's going to affect the ability to orient by using landmarks. When we talk about the hippocampus and about neuroimaging [in humans], we don't really have the detailed information that we do for rodents because in humans, we cannot enter the hippocampus of healthy controls and record neurons from there. But we use neuroimaging, which provides more of a microscopic picture of what's happening. There's no electrophysiology that can really help [in studies on humans], although we do have evidence.

"WHAT IS A COGNITIVE MAP? HOW DO YOU BUILD IT?"

So we look at the hippocampus and we detect increased Blood Oxygenated Level Dependent Signal within the hippocampal region, suggesting increased neural activity. We don't measure single cells, so the information is a little bit different [from that of rodents]. We also have structural information within the hippocampus that confirms that it's really critical for orientation and specifically, for cognitive maps. For example, there has been evidence provided in the last ten years about taxi drivers. Taxi drivers move within their environment daily for an enormous amount of time. They have a huge, detailed [cognitive] map of the environment. In London, Eleanor Maguire and her colleagues showed that if you measure the volume of the hippocampus of taxi drivers, you can see that the right hippocampus is bigger when compared with the hippocampus of non-taxi drivers living within the same city.[2] The second point that I wanted to make is that when we think about topographic orientation, we think about critical regions [of the brain] that we know are important (for example, the hippocampus, but also the parietal cortex) What the majority of scientists investigating this [subject] are interested in is connectivity. We are interested in the network, not just specific regions because what we have understood in the last few years is that in the brain, what really makes a difference, is not just a specific region, but how the regions communicate with other regions. If you think about the first comment that I made about the complexity of orientation and navigation in humans, which involves different cognitive skills and [therefore] different brain regions, you'll easily realize that the connectivity must be very relevant in order to assess the neural mechanisms that are responsible for orientation.

I mentioned that for studies in humans, we don't really have electrophysiological measurements within the hippocampus. This is not totally true because in order to localize the epileptic focus of patients with epilepsy, neurosurgeons used to insert microelectrons within the temporal lobe. Sometimes, in order to detect the discharge of these neurons and then remove that part of the brain that has the epileptic focus, neuroscientists like me use these patients to see how neurons are responding while they are doing some hippocampo-dependent orientation task. We do have electrophysiological measurements, but mainly in a clinical population.

WE ARE INTERESTED IN THE NETWORK, NOT JUST SPECIFIC REGIONS...

**RS:** ***Are we at a point with how we can investigate the brain where we know if the structural organization of the hippocampus and the connectivity between the hippocampus and other regions of the brain is more due to genetics or development?***

***GI:*** That's a very big question mark for us. There are a lot of people doing developmental studies in terms of connectivity, and if you think about the neuroanatomy, you can easily realize it has to do with development. You develop new skills, you develop your brain, your cortex is folding more and more: the baby grows and the baby experiences the environment. So, clearly there is a change in your anatomy, which basically means there is a change in the connectivity. Is this change determined genetically? The answer is most likely "yes," but we don't actually have evidence yet. People who are actually investigating this are interested in developmental disorders, just to see if there is any way we can detect a gene or a series of genes that will tell us about the development of specific cognitive skills. We do have the ability to detect functional connectivity and also structural connectivity, but we don't really have evidence yet that the variability across individuals in terms of connectivity can be referred to genes.

**RS:** ***Switching gears a bit, you made a very interesting comment in* The Denver Post *that alluded to GPS technology as a contributor to the deterioration of mental mapping skills.***

**GI:** The reason why I made this comment is to illustrate a point: let's say you move to New York and you buy a car with a GPS. You will use it everywhere you go, so you never use your brain. You will not have a mental map of New York. If you


*"Compass Inlay" Compass Rose, Terminal Tower, Cleveland, Ohio, 2010. Photo courtesy of flickr member, Steve Snodgrass.*

# Compass Rose

The compass rose has been around as long as the Portolan charts that emerged in Spain and Italy in the 13th century. Portolan charts, lovely for their detailed and colorful illustrations of harbors and trade routes of the Mediterranean, were ornamented by the compass rose, which was created to show the direction of winds, a factor that was important to Mediterranean traders. The compass rose contains 32 points, which indicate the directions of the eight major winds, the eight half-winds and the sixteen quarter-winds. The colors on the compass rose were created to ensure visual clarity for seafarers viewing Portolan charts in the dark of night on rolling ships. That's why the eight major winds on the compass rose are often prominently displayed in black to be easily seen against the lighter background and other trade-wind colors, the half-winds generally being blue or green and the quarter-winds being red.

do this over and over again, you do not practice your skill, which means the regions in the brain that are responsible or that put effort into supporting your skills of creating cognitive maps will do something else. In some way, then, you will lose the ability to create cognitive maps. In other words, if you use GPS, you replace your neuronetworks responsible for creating the maps. Then you always have to rely on GPS because those regions in the brain responsible for creating maps may become responsible for something else; that's the evolution, that's the way it goes. Having said that, I don't really have anything against the use of GPS as long as it's used properly. Many people with DTD are able to move around just because of GPS, so the advantage is huge. I don't like black and white comments on things like that. It's an extremely useful tool if you really need it. It's fun. You can use it as long as you are aware of the effect of the technology.

**RS:** ***Do you use GPS?***

**GI:** I don't have GPS [laughs]. But, for example, I went to Lethbridge [in Alberta] for a seminar, and I usually don't use any technology, but I was getting late and used my iPhone to track my directions. I do realize it's very useful, and sometimes, it's very critical to use it. I trust my brain more, at least now. When I'm 75, I'll trust it less.

**RS:** ***I always like to look at a map—I like to see where I am—before I use a GPS.***

**GI:** It also becomes more personal, and on the psychological side, it becomes more interesting. We're doing a study in our lab now where we ask people that make use of GPS and people that do not to solve a variety of orientation tasks that assess different orientation skills. What we are finding so far is a trend where people that make use of GPS do worse in our orientation tasks. I don't really know what this means in terms of neural mechanisms, but it basically means that if I take away the toy from these people, they will not perform the task as other controls do. There's only one study showing that if people have to use a technology aid for finding their way in the environment, then they find their way in a real surrounding differently.[3] What we are doing now is assessing a variety of orientation skills in users and in non-users, and we're already finding a trend, which basically means we just need more subjects in order to provide significance to this trend. But the trend is there.

**RS:** ***I wanted to end by asking you if your research has influenced or changed your own relationship to maps, cognitive and otherwise.***

**GI:** Sometimes people assume that I do have orientation problems because I have so much interest in all of this research. I don't actually. I think I have an average, maybe a bit below average orientation ability, but I am very aware of the environment. I am very biased in trying to look at landmarks or trying to remember things about locations; I'm too much aware of my knowledge to be detached and to be so naive about the environment. If I walk along a new pathway, I usually turn around seven or eight times, just to see how things will look when I'm going back. I'm really biased because of my knowledge. I think it helps me to appreciate a little bit more the information that's available in the environment. I look at people, and I'm really interested to sometimes ask them questions to see how they give directions and information. I like to experience the environment, because I think I've developed some knowledge through the years of how our brain works in the environment. It's fascinating because it's very, very complex.

***To learn more about Dr. Iaria's research on Developmental Topographical Disorientation, visit http://www.gettinglost.ca***

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## ENDNOTES


1. O'Keefe, J, Nadel, L. (1978) *The hippocampus as a cognitive map*. Oxford: Clarendon Press.
2. Maguire, E., Gadian, D. G., Johnsrude, I. S., Good, C. T., Ashburner, J., Frackowiak, R. S. J. & Frith, C. D. (2000) "Navigation-related structural change in the hippocampi of taxi drivers," *Proceedings of the National Academy of Sciences* U.S.A 97(9), 4414-6.
3. Ishikawa, T., Fujiwara, H., Imai, O. & Okabe, A. (2008)."Wayfinding with a GPS-based mobile navigation system: A comparison with maps and direct experience," *Journal of Environmental Psychology* 28(1), 74-82.


## FURTHER READING


Hutchinson, A. (2009, November) "Global Impositioning Systems: Is GPS technology actually harming our sense of direction?" *The Walrus*. http://www.walrusmagazine.com/articles/2009.11-health-global-impositioning-systems/