EMILY BRAIN AND DAVID BILKEY

Hippocampal Astrolabe: Navigating Places in the Mind

EMILY BRAIN

Working with David Bilkey, from the Department of Psychology at Otago University, I had the opportunity to learn a great deal about a subject I would not normally encounter. David's area of research is "place cells." These cells are located in an area of the brain called the the hippocampus. They fire—become active—when an animal (including the human animal) is in a specific location within their environment or there is a perceived change in "place." Each cell fires in response to one or more particular "place fields." The place cells activate in sequence as you move throughout your environment, creating a cognitive map.

Looking at images of place cells firing in the brain of a rat, I realised the patterns resembled star clusters, and those firing cells were in direct relation to a physical space. I imagined the place cells as a 3D map that, if deciphered, could be used to locate a place, or path, taken using the necessary pattern of fired cells, or vice versa. I recalled that when I was in primary school I constructed a basic planisphere from a printout on cardboard. The correlation between the movement of the stars and the rotation of the earth, due to our relative position in time, fascinated me even before I understood it. I turned the disks to the day's date and thought "I am here," and then matched the cardboard stars to the real ones. The stars became solid measurable proof of my location in time and space.

A planisphere works using stereographic projection.[1] It has is two disks that rotate on a common pivot. The bottom disk is a star chart, the other has an oval hole cut out. When aligned to different dates and times around the outside of the disk, a portion of the star chart shows through the oval hole, corresponding to the stars visible in the sky on that date, at that hour, at a particular latitude. It is useful for locating and identifying stars, constellations, and other celestial bodies. The planisphere shares a common history with the astrolabe. Astrolabes are older, more complex versions of planispheres. An astrolabe has a similar basic structure of rotating disks called the *mater* (base disk), *tympan* (engraved plate), and *rete* (engraved framework disk).[2] The disks are marked with altitude and other spherical measurements, a declination scale, degrees of arc, and pointers indicating particularly bright stars, in addition to the oval indicating visible stars. The astrolabe can be used to predict the positions of the Sun, Moon, planets and stars, and to determine local time in a given latitude. They are also used in triangulation and surveying. They were invented between the second century BC (generally attributed to Hipparchus) or later, closer to the fourth century AD, and became ever more elaborate and complex as the geometry of the projections was refined. Made of brass, they were an instrument for the wealthy. Cheap paper astrolabes became available with the development of printing technologies, although few survive. From the second half of the seventeenth

Figure 1. Antique astrolabe influenced by the Regnerus Arsenius school in Louvain, Collection of the Museum of History of Science in Oxford.

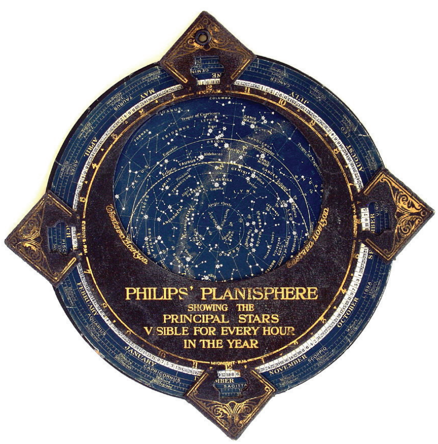

Figure 2. Philip's Planisphere (Latitude 51.5 North), ca. 1900, was invaluable for both beginners and advanced observers. The map is designed by the well-known celestial cartographer Wil Tirion.

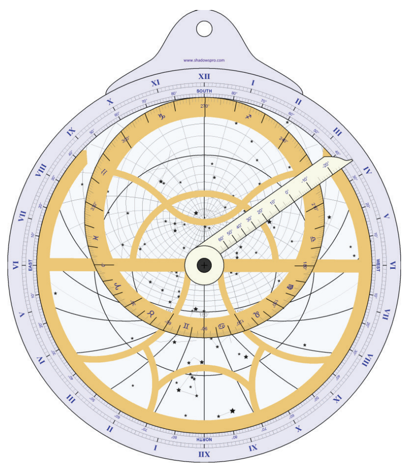

Figure 3. Modern day planispheric astrolabe designed for the latitude of Varese (Italy), drawn by the *Shadows Pro* shareware. Printable on paper.

century the popularity of the astrolabe waned, with developments in accurate chronology (pendulum clock) and more specialised astronomical instruments, such as the telescope.[3]

Many planispheres, such as the Philip's, included maps with the positions of several deep-sky objects, such as the Pleiades, the Andromeda Galaxy and the Orion Nebula, as well as major stars down to magnitude 5.[4] Major constellations are used as signposts to navigate the night sky, useful for locating and identifying stars and other deep-sky objects. Because the planets move round the Sun, their positions in the sky are constantly changing and they could not be marked permanently on the map of the planisphere. However, on the back of the planisphere were tables giving the predicted positions of planets such as Venus, Mars, Jupiter and Saturn for every month until 2020.

Thinking of star cluster maps and movement over time, I found my old cardboard planisphere and began to design my own tool for relating hypothetical cells to real-world coordinates, a generalized "place field." The tactility of the movement of the discs was important to me. The kinetic movements, when rotating the disks, gives you more of an experience of physically locating yourself in relation to your environment than a static wall chart. The lines around the outside of the disks correlate to coordinates, one disk for the longitude, one for latitude. The disks were marked with "cells," half-dark and half-light, showing the cells from the hippocampus of the left and right hemispheres of the brain. When the coordinates of the two disks are chosen, they are pointed to using the third disk, a pointer and frame, which indicates the particular cell combination that is firing in the "place field" at those coordinates. Place cells form a representation of a specific location in space and thus form a cognitive map. The "Hippocampal Astrolabe," was designed as a tool for matching geospatial coordinates

Figure 4. Emily Brain, *Hippocampal Astrolabe*, 2016, 20cm x 20cm (Photograph by Sarah McKay).

in the real world with those in a potential "place field"—with the hypothetical place cells that might fire if you were in that environment. The "Hippocampal Astrolabe" allows one to navigate the topography of imaginary places, using sophisticated ancient navigation technology and allowing you to explore possible places or states of mind associated with a particular cluster of place cells.

Figure 5. Emily Brain, *Hippocampal Astrolabe*, 2016, 20cm x 20cm (Photograph by Sarah McKay).

Figure 6. Emily Brain, *Hippocampal Astrolabe*, 2016, 20cm x 20cm (Photograph by Sarah McKay).

DAVID BILKEY

I particularly enjoyed working with Emily on this project. It was great to see her take ideas around the notion of a cognitive map (an internal representation of space within the brain) and transform them into this navigational tool, the *Hippocampal Astrolabe*. In my area of research there is a lot of discussion about the role of the hippocampus in assisting people and other animals to navigate through their physical and mental world. It turns out that the hippocampus is particularly important for piloting, the process whereby we determine our position with reference to external landmarks. Astrolabes were also used to determine position, although in this case with reference to the sun, moon and stars, rather than stable landmarks. Emily has grabbed this idea and run with it, in the process hinting at the newly discovered role of the hippocampus in predicting future pathways through space and in aiding the consolidation of memory during sleep.

Emily Brain is an Australian-born Jewellery and Metalsmithing student, currently in her third and final year at the Dunedin School of Art. Her work explores relationships between people and everyday objects, using a variety of traditional silversmithing and textile materials and processes.

David Bilkey is Professor of Psychology at the University of Otago. His general research area is systems neuroscience, with a particular focus on the role of the temporal cortex regions of the brain in memory and learning processes. This work uses a combination of electrophysiological and behavioral procedures to determine how these temporal area structures normally operate, how they interact with regions such as the prefrontal cortex, and how they malfunction in diseases such as schizophrenia.

1. James. E. Morrison, *History of the Astrolabe*, The Astrolabe (website), http://www.astrolabes.org/pages/history.htm
2. Hughes, D. W. and C. Stott, "The Planisphere: A Brief Historical Review," *Journal of the British Astronomical Association*, 105:1, 35-9 http://adsabs.harvard.edu/full/1995JBAA..105...35H (accessed 7 November 2016).
3. Darin Hayton, "An Introduction to the Astrolabe," http://dhayton.haverford.edu/wp-content/uploads/2012/02/Astrolabes.pdf The first major writer on the projection was the famous Claudius Ptolemy (ca. AD 150) whose ideas were outlined in his *Planisphaerium*.
4. Astronomers define star brightness in terms of apparent magnitude (how bright the star appears from Earth) and absolute magnitude (how bright the star appears at a standard distance of 32.6 light years, or 10 parsecs).