

ELEANOR MAGUIRE

Eleanor Anne Maguire

27 March 1970 – 4 January 2025

elected Fellow of the British Academy 2018

by

CHRISTOPHER D. FRITH

Fellow of the Academy

Summary. Eleanor Anne Maguire was an Irish neuropsychologist renowned for her groundbreaking research into human memory, spatial navigation, and the role of the hippocampus in these processes. She served as Professor of Cognitive Neuroscience at University College London (UCL), where she was also a Wellcome Trust Principal Research Fellow and Deputy Director of the Wellcome Trust Centre for Neuroimaging. She was a pioneer in the use of neuroimaging and virtual reality to study human memory in ‘real-life’ scenarios. Her most famous work involved studying London taxi drivers, demonstrating that acquiring ‘The knowledge’ was associated with an increase in the volume of part of their hippocampus. This result demonstrated that the human brain remains plastic and can form new connections in adult life. Having shown that the human hippocampus is involved in navigation as well as memory, Maguire developed ‘Scene Construction Theory’. This theory unifies a range of cognitive functions and has had a significant impact on the field of memory research.

Biographical Memoirs of Fellows of the British Academy, 22, 727–744

<https://doi.org/10.5871/mem/022.727>

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Eleanor Maguire

Life

Eleanor Anne Maguire was born in Dún Laoghaire, County Dublin, Ireland, on 27 March 1970. Her parents, Anne and Paddy, have deep roots in the Dún Laoghaire neighbourhood. Having been born and raised there themselves, they worked in Dún Laoghaire and raised their own family there too. Paddy was a manufacturing operative, and Anne was a hospital secretary and receptionist. Eleanor also had a close relationship with her brother, Declan Maguire (1965–2019), who was a supply chain manager for a local pharmaceutical company; and she delighted in the company, lives and characters of her two nephews.

By all accounts, including her own, Eleanor was a studious young girl with a deep curiosity and love of learning. Even at primary school (Our Lady of Good Counsel Girls' National School) she was so focused on her studies that she regularly had to be cajoled from her room to come to the dinner table. Eleanor characterised herself as having an insatiable thirst for facts. She aimed for 100 per cent in all subjects and was upset by anything less. She would study for hours, sometimes until 2 o'clock in the morning. She did not have any particular favourite subjects but wanted to excel in all of them. She came top even in Irish Language, which was her least favourite subject.

Eleanor was the first in her family to go to university. She completed her Leaving Certificate examinations at the Holy Child Community School with honours in English, Irish, French, maths, history, geography and art, and had to choose what to do at university (University College Dublin). Although science subjects did not figure in her Leaving Certificate, Eleanor chose to focus on some aspect of science in university. The reason she gave for this choice reveals that her childhood had not been completely dominated by work. She was a *Star Trek* fan with a special interest in Mr Spock, science officer onboard the starship *Enterprise*. Eleanor stated that, 'he embodied so much of what attracted me to science; he was inquisitive, logical, honest, meticulous, calm, fearless in facing the unknown, innovative and unafraid of taking risks; science was exciting on board the *Enterprise*, their cutting-edge technology to be envied.' This interest in cutting-edge technology and honesty remained a major feature of her scientific career.

University

Within science, Eleanor had three special interests: archaeology, astronomy, and biology. Her parents convinced her that there was no money in archaeology, and Eleanor herself felt that to study astronomy in Dublin in the late 1980s was 'pie in the sky'. This left biology. Eleanor soon discovered that the 'wet lab' was not for her, so that left psychology. Apart from the biological aspects, she found this topic somewhat disappointing, but

in her final year a new module on neuropsychology was introduced. This was taught by Teresa Burke who had just returned to Ireland after completing a postdoctoral fellowship in Canada under the guidance of Brenda Milner. Once Eleanor had started this neuropsychology module, she was hooked. 'The brain – here was something tractable that challenged and completely absorbed (me).' She was not satisfied with the bare bones of this course but always wanted to know more. With her undergraduate project on *egocentric vs allocentric representations of space* the scene was set for her future career.

A Master in Neuropsychology

Eleanor had decided to devote her future career to research in neuropsychology. So, in 1990, she moved to Swansea University to study for an MSc in Experimental and Clinical Neuropsychology under the supervision of Alan Beaton and Graham Beaumont. Eleanor was dedicated to her studies and spent most of her spare time reading. Not surprisingly she obtained a distinction. She is described by one of her fellow students at this time as 'a woman on a mission to learn as much as she could'. Despite not joining her classmates in pubs or nightclubs, she was popular and well liked. She enjoyed informal discussions with the other MSc students in which she liked to think up ways of experimentally testing the outlandish hypotheses that sometimes emerged. This practice was critical for her future research in which she frequently chose to explore processes that many of her colleagues believed to be experimentally intractable.

As part of her degree course Eleanor was required to carry out and write up a piece of independent research. The topic she chose to investigate was dual task performance and whether this ability to do two things at once was affected by handedness. One idea behind such studies was that interference between tasks will occur when both tasks involve the same brain area. So, since both speech and movement of the fingers of the right hand are controlled by the left hemisphere, there should be more effect of speech on right hand movements than on left hand movement. Another idea was that results depended on which hand was dominant. Eleanor designed an experiment to distinguish between such theories.

As is all too often the case, her careful experimentation and analysis revealed that none of the theories was adequate to explain the results. Eleanor concluded that a key, but unexamined, variable concerned the allocation of attention to the two tasks. In her careful control of the experimental procedures, her choice and manipulation of response measures, as well as in the economy of her exposition and the clarity of her thought, Eleanor demonstrated a scientific maturity that is rare in someone who had only recently completed her first degree.

The role of the hippocampus in spatial navigation

After her MSc, Eleanor returned to Ireland and the supervision of Teresa Burke to embark on a PhD at University College Dublin. Thus, since Teresa had previously worked with Brenda Milner, Eleanor can be considered an academic descendant of Brenda Milner who was the first to demonstrate the role of the human hippocampus in memory.

Eleanor and Teresa were based in the neurosurgery section of the Beaumont Hospital in Dublin. It was here that Eleanor's stellar career in research began. Her doctoral thesis was titled 'Real-world spatial memory following temporal-lobe surgery in humans'. This study contains many of the elements that subsequently characterised Eleanor's research style. She recognised the importance of studying cognitive deficits resulting from brain damage, and she tried to make her experimental procedures as close to real life as possible.

In the early 1990s there were no dedicated clinical neuropsychologists in Ireland, leaving clinical assessment of patients purely to academics like Eleanor. Many of the patients she saw were having brain surgery for the treatment of epilepsy and she had to decide what she was going to do with them.

I read this paper (The hippocampus as a cognitive map),¹ and it cemented everything. First, it contacted with something personal, my complete inability to find my way around, something that plagues me to this day. Second, navigation problems were prevalent among these patients in their everyday lives, thus affording the opportunity to study something meaningful.

Memory problems were well established in such patients, but not problems with wayfinding. Forty years earlier, Brenda Milner had shown that damage to the hippocampus caused major impairment to episodic memory; the ability to remember events from the recent and distant past. The primary evidence came from Patient HM, who suffered from intractable and incapacitating epileptic seizures, and had been subjected to brain surgery involving removal of the hippocampus and some surrounding tissue from both sides of the brain.² Immediately after the operation HM could no longer remember anything of the events of his day-to-day life. This problem persisted for the rest of his life. At the same time his understanding and reasoning seemed unaffected, and he could learn new skills.³ The critical role for the hippocampus in episodic memory was subsequently confirmed.⁴

¹O'Keefe & Nadel (1979).

²Scoville & Milner (1957).

³Squire (2009).

⁴E.g., Tulving & Markowitsch (1998).

There was, however, a very different story concerning rats. John O'Keefe had discovered place cells in the hippocampus of the rat. These are nerve cells that become active whenever the rat is in a particular location in its environment. O'Keefe proposed that these cells were the basis for a map of the spatial environment within the brain,⁵ work for which he was awarded a Nobel prize in 2014. So, in rats, there was a critical role for the hippocampus in spatial navigation. The aim of Eleanor's PhD was to demonstrate that the hippocampus had a critical role in spatial navigation in humans also.

The way she went about this project has characterised her work ever since. She was determined that the study should not be like a laboratory experiment, but as close to real life as possible. She persuaded two friends, one of whom was a professional cameraman, to make films of routes through an urban area (Blackrock) in Dublin. The films were taken from a motorcycle with the cameraman on the back, and the routes were seen at eye level from a first-person point of view. Virtual reality was not available at that time, but it is no surprise that when this did become available, Eleanor was one of the first neuroscientists to use it.⁶

Two of the Dublin route videos were shown several times to 20 patients who had received unilateral surgery on the temporal lobe (including the hippocampus) for intractable epileptic seizures. The videos were also shown to 10 healthy volunteers. Great trouble was taken to make sure that everyone learned the routes and when tested afterwards, all were able to recognise scenes from the videos, but the patients were markedly impaired when tested for knowledge of the routes. For example, the participants were asked to draw maps of the routes. All maps drawn by the controls were rated as being accurate to the point where the maps could be used to navigate successfully in the area. None of the patients' maps were rated to be similarly accurate. Figure 1 shows some examples of the maps that were drawn.

This study was the first to show that temporal lobe lesions in humans could impair spatial navigation and strongly implicated a role for the hippocampus. John O'Keefe, who examined Eleanor's PhD thesis, was very impressed by this work which he cited⁷ in the same year as Eleanor's publication.⁸ John encouraged Eleanor to move to the Functional Imaging Laboratory (FIL) in London, initially at the Hammersmith Hospital, and subsequently at Queen Square, where she spent the rest of her career.

Eleanor joined the FIL in 1995 working with Chris Frith. The study of schizophrenia, on which she was supposed to be working, never got off the ground due to problems with ethical protocols and the recruitment of patients. This was lucky because it meant that

⁵O'Keefe & Dostrovsky (1971).

⁶Maguire *et al.* (1998).

⁷Burgess & O'Keefe (1996).

⁸Maguire *et al.* (1996).

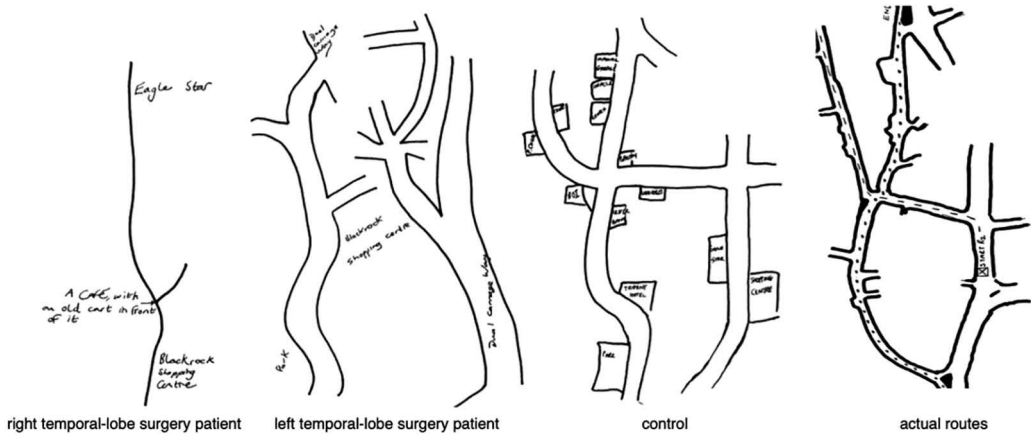


Figure 1.

Eleanor continued with her work on spatial navigation. These studies were so successful that it became obvious that this should be her focus, and she soon had her own research group.

Eleanor's research was always marked by the adoption of new technologies. She enthusiastically adopted new brain imaging technology and, in a series of studies using Positron Emission Tomography (PET), confirmed a role for the hippocampus in spatial navigation.⁹ Activity in the hippocampus increased when subjects had to remember film footage of navigation through an urban environment and also when taxi drivers had to recall routes around London. She concluded that the hippocampus is involved in processing spatial layouts over long as well as short time-courses, and that it participates in both the encoding and the retrieval of topographical memory.

The Taxi Driver study

The much-acclaimed TV play 'The Knowledge' was first broadcast in 1979. This is the story of four unemployed men who want to become licensed London Black Cab drivers. To do so they need to acquire 'the knowledge', which involves learning 15,800 streets and 468 set routes in London and then passing a rigorous test. This feat of memorising involves riding around every part of London on a moped and typically takes about four years. Not everyone manages it. London is the only city in the world where taxi drivers have traditionally been required to acquire such detailed knowledge, a skill that has sadly been rendered largely obsolete by the advent of satellite navigation. Eleanor saw

⁹Maguire (1997).

‘The Knowledge’ when it was rebroadcast in the 1990s. Recognising that London taxi drivers were a unique group of people who had acquired a very high degree of spatial navigation skill, she wondered whether this incredible memory feat might generate detectable changes in brain structure.

For most of the 20th century the idea of brain plasticity in adulthood was rejected, and it was widely believed that neural connections in the adult brain were fixed and immutable,¹⁰ but, from the 1970s onwards, evidence against this position was beginning to emerge. One early line of evidence came from studies of birds.¹¹ Species that store food for future use (caching) need good spatial skills to remember where the food was stored, and such species tend to have a larger hippocampus than non-caching species. Furthermore, caching increases during late autumn and early winter and this behavioural increase is accompanied by an increase in hippocampal volume and cell number. In humans there was evidence that special skills, such as musicianship, are associated with detectable differences in brain structure – even in adulthood.¹²

These developments justified Eleanor’s plan to study brain structure in London taxi drivers. To do this she gathered a team of experts in imaging and the measurement of brain structure using Magnetic Resonance Imaging (MRI). Two methods were used to compare the brain of 16 taxi drivers and 16 controls.¹³ The first method, Voxel Based Morphology, is a purely statistical technique for measuring volume of grey matter. Differences between the groups were found in only two brain regions: the left and right hippocampus. The second method, pixel counting, measured the volume of the hippocampus directly by counting the number of pixels¹⁴ in the hippocampus across a series of brain slices, thereby estimating the cross-sectional area of the hippocampus in each slice. This technique revealed that the taxi drivers had a greater posterior hippocampal volume than the controls – an effect that was even more pronounced in taxi drivers with more experience. These results strongly suggested that acquiring ‘the knowledge’ and becoming a skilled navigator altered the structure of the hippocampus (rather than the other way round).

Many people found this result entertaining because it seemed to contradict the stereotypical view of London taxi drivers as opinionated rather than brainy. So, somewhat to Eleanor’s surprise, her result was taken up in a big way by the media. For example, the study received a big splash on the BBC news at the time (March 2000). The news item included the headline ‘Taxi drivers’ brains “grow” on the job’ and a quote from a taxi driver, ‘I never noticed part of my brain growing – it makes you wonder what happened to the rest of it’.

¹⁰ See Will *et al.* (2008).

¹¹ Lee *et al.* (1998).

¹² Schlaug *et al.* (1995).

¹³ Maguire *et al.* (2000).

¹⁴ Pixels (picture elements) are the basic units from which the brain image is built.

It was inevitable, after all this publicity, that Eleanor's study drew the attention of the IgNobel prize committee. This was the kind of result that they liked to promote: something that first makes you laugh, and then makes you think. Eleanor was understandably worried that being awarded such a prize might not be so good for her career. People might take her less seriously. She was applying for a Wellcome Fellowship at the time. Various negotiations took place in the background to delay the awarding of the prize until after she got her fellowship. So, it was not until October 2003 that she went to Harvard to receive her IgNobel prize. Eleanor rather enjoyed this experience, which included her taxi driver spontaneously reducing her fare in appreciation of her study.

Since this landmark study, further evidence emerged demonstrating that intensive practice can cause changes in brain anatomy as well as brain function. For example, learning to juggle can cause selective structural changes in brain areas that are associated with the processing and storage of complex visual motion.¹⁵ However, Eleanor was well aware that her study could not definitively demonstrate that the work done to acquire 'the knowledge' had caused the hippocampus to change. Her experiment was an example of what is called a 'quasi experimental design' because it compared existing groups, taxi drivers and a mixed group of controls who weren't tax drivers, without controlling for the multiple factors that determine whether a person becomes a taxi driver or not. The task of acquiring 'the knowledge' may therefore not have been the only difference between taxi drivers and the control group. In ideal experiments people would be randomly assigned to be taxi drivers or controls (which would, of course, be impossible) with cause and effect tested by investigating whether the hippocampus changes following training.

One feature of the taxi drivers not shared with the controls was the daily experience of driving through the excessively busy streets of London. Recognising this problem, Eleanor carried out a second study in which taxi drivers were compared with London bus drivers.¹⁶ London bus drivers also have the daily experience of driving through the busy streets of London, but do not have to navigate since they follow a highly constrained set of routes. The results of this study replicated those of her 2000 study, with greater grey matter volume in posterior hippocampus of the taxi drivers than the bus drivers, and this difference correlated with years of navigation experience only in taxi drivers.

Another possibility was that the taxi drivers had a different hippocampus from the controls even before they acquired 'the knowledge'. People with such a hippocampus may be better able to navigate and are therefore more likely to become taxi drivers. To address this problem, Eleanor conducted a longitudinal study in which trainee London taxi drivers were assessed at the start of the training and then again 3–4 years later after

¹⁵ Draganski *et al.* (2004).

¹⁶ Maguire *et al.* (2006).

completion of the training.¹⁷ A control group was included who received no training. As is typically the case, about half of the trainees failed to qualify.

Prior to training, the three groups (trainees who passed, trainees who failed, and controls), did not differ on any of the tests of memory or in the volume of any brain region. After training several differences emerged. Whether successful or not, the trainees displayed more knowledge of the spatial relationships between landmarks in London than the controls. However, only the successful trainees showed any change in brain volume. Every one of them showed an increase of grey matter volume in the posterior hippocampus. No such change was observed in the unsuccessful trainees or the controls. This result confirmed that the changes in brain structure were caused by successful training needed to acquire ‘the knowledge’.

Based on this result and on her many previous studies, Eleanor concluded that there is a capacity for memory improvement and concomitant structural changes to occur in the human brain well into adulthood.

The importance of introspection

Eleanor’s fascination with *Star Trek* influenced not only her decision to become a scientist but also the way she conducted her science. ‘My desire to study a cognitive phenomenon or behaviour such that the examination of it does not divert it from its natural course or how it would occur in the real world, owes much to Starfleet’s General Order #1.’ In *Star Trek*, this order, commonly referred to as ‘the prime directive’, stated that there must be no interference with the internal development of alien civilisations. This is what motivated Eleanor to make her experimental tasks as close to real life as possible.

Another feature of real life that Eleanor very much respected was introspection. In the early days of brain imaging no one thought to ask what people were thinking about as they lay in the scanner. There was a belief, left over from the dominance of behaviourism in the early 20th century, that data obtained from introspection was neither reliable nor valid. This belief was abandoned when the ‘cognitive approach’ emerged at the end of the century. As Eleanor recognised, the investigation of phenomena such as episodic memory critically depends upon introspection.

Using introspecting has helped me to decompose complex thoughts and behaviours to make them amenable to investigation. In addition, debriefing subjects following an experiment, having them introspect on how they performed a task, can provide valuable insights into their priorities and strategies. Some people frown upon introspection and regard this information as unreliable, while I on the other hand am disappointed when experimenters don’t include it.

¹⁷Woollett & Maguire (2011).

This combination of realistic tasks and the use of introspection is nicely illustrated by another imaging study of London taxi drivers conducted with her post-doctoral fellow Hugo Spiers.¹⁸ The taxi drivers were scanned while they drove through a highly realistic virtual reality version of central London. A series of ‘customers’ would request to be driven to particular locations. The innovative feature of this study occurred after scanning was over. What the drivers had seen during their navigation through London was videoed. They were shown these videos and asked to describe what they remembered thinking. The drivers were able to produce remarkably detailed accounts of what they had been thinking during navigation.

Customer (at Buckingham Palace): *Hi, could you take me to Shepherd Market, please.*
 Driver: First of all I was thinking shall I reverse, spin round and go up Marlborough Gate, Marlborough Road, and I thought no, I’ll do it the way I would do it, and it’s Constitution Hill, round Hyde Park Corner, Park Lane, Stanhope Gate. That’s what we’re looking for.

The statements that made up these accounts were classified into different categories, such as *route planning*, *visual inspection*, or *expectation violations*, and then linked with the brain activity occurring at that moment during scanning. This analysis showed that the thoughts that unfolded during navigation were associated with clearly distinct patterns of brain activity. For example, the first few seconds of route planning were associated with increased activity in the hippocampus, while visual inspection was associated with activity in occipital (visual) cortex. In addition to adding to our understanding of brain function linked to navigation, these results also confirmed the validity of the introspective reports.

A common feature of human mental life that can only be studied via introspection is mind-wandering. This is when attention shifts away from the current task and towards internally generated thoughts and feelings. Mind-wandering occupies a large proportion of our waking hours. Eleanor noted that two of the most prominent features of mind-wandering are mentally travelling forward and backward in time and visual imagery. These are functions usually associated with the hippocampus. This led her to predict that mind-wandering in patients with hippocampal damage should differ from that of controls. She was able to confirm this prediction in a study of six patients with bilateral hippocampal damage.

The controls thought mostly about their past, present, and future, imagining vivid visual scenes: ‘I am remembering a discussion I had with my friend at King’s Cross concourse a few weeks ago. I can see the scene clearly in front of me.’ In contrast patients with hippocampal damage thought primarily about the present, having verbal and semantic thoughts rather than episodic thoughts. For example, one patient reported: ‘I am self-pondering. Am I a creative person?’¹⁹

¹⁸ Spiers & Maguire (2006).

¹⁹ McCormick *et al.* (2018).

Scene construction theory

Another of Eleanor's major contributions to cognitive neuroscience was the development of 'scene construction theory'. Introspection played a major role in the studies used to develop this theory.

Eleanor had shown that the hippocampus in humans had a key role in spatial navigation, just as it did in rats. But this raised a new question. In humans the hippocampus also has a key role in episodic memory. So, what is the link between spatial navigation and episodic memory? Is there a common cognitive process instantiated in the hippocampus that links the two abilities?

Since the pioneering work of Frederic Bartlett²⁰ it has been recognised that episodic memory is not simply a replaying of events that happened in the past. It is a constructive process that can be subject to distortions and errors.²¹ Memory for an episode is created by stitching together remembered components of the original event into a plausible narrative. But stitching features together to form a plausible narrative does not just apply to episodic memory. It also operates when we think about what might happen to us in the future.

There were already hints that amnesic patients are not good at thinking about their likely future.²² With her PhD student Demis Hassabis,²³ Eleanor took this idea a step further and explored whether amnesic patients could imagine any novel experience. As with her previous work on navigation, Eleanor used a two-pronged approach: Studying patients with damaged brains and measuring brain activity in healthy volunteers. In one study,²⁴ 10 patients with amnesia associated with hippocampal damage, as well as healthy volunteers, were asked to imagine new experiences. Consistent with Eleanor's expectation, the key finding was that the patients' imagined experiences that consisted of fragmented images at most and lacked spatial coherence. This is illustrated in the following responses from one patient.

Experimenter: *Imagine that you are standing in the main hall of a museum containing many exhibits*

Patient: To be honest there's not a lot coming.

Experimenter: *Do you hear anything or smell anything?*

Patient: No, it's not very real. It's just not happening. My imagination isn't...well, I'm

²⁰ Bartlett (1995).

²¹ Schacter *et al.* (1998).

²² E.g., Klein *et al.* (2002).

²³ CEO of Google DeepMind, Noble Prize for chemistry 2024.

²⁴ Hassabis *et al.* (2007a).

not imagining it. Let's put it that way. Normally you can picture it, can't you? I'm not picturing anything at the moment.

Experimenter: *So, are you seeing anything at all?*

Patient: No.

In a second study²⁵, healthy volunteers were scanned while they imagined novel fictitious experiences (e.g., 'Imagine you are lying on a sandy beach in a tropical bay'). These 'creative' trials were contrasted with trials in which the volunteer recalled a genuine event from the past (an episodic memory).

The results revealed an extended brain network, including the hippocampus, that was active when volunteers were imagining new fictitious experiences, and also when they remembered their own real personal experiences. There were also brain areas that were active only during episodic memory recall (anterior medial prefrontal cortex and posterior parietal cortex). These areas have been associated with self-reflection and might thus distinguish between things that have actually happened (episodic memories) and imagined experiences that never happened.

A summary of these results²⁶ proposed that scene construction was not only a key component of spatial navigation and episodic memory, but also of episodic future thinking, imagination and vivid dreaming. Damage to the hippocampus has an impact on all these processes. However, each of these processes involved interactions between hippocampus and other brain regions depending on which process is active.

Construction is the key word in scene construction theory. It reminds us that the internal representation in our brain is not the actual scene, but a reconstruction from the evidence provided by our senses. Furthermore, this construction even goes beyond the information provided by the senses. We make inferences about the edges of the scene that go beyond what we can actually see. This phenomenon is known as *boundary extension*. Because these inferences about the boundaries are not constrained by sensory input, they can sometimes be in error and observers report seeing more than was actually there.

These observations led Eleanor and her colleagues to make a counter-intuitive prediction. They reasoned that, if patients with amnesia lack the ability to construct scenes, then they will not be able to make these boundary extension errors. In other words, patients with amnesia will be more precise in their immediate memory for scenes than healthy controls. This prediction was tested in 7 patients with severe long-term memory problems associated with hippocampal damage.²⁷

²⁵Hassabis *et al.* (2007b).

²⁶Hassabis & Maguire, (2007).

²⁷Mullally *et al.* (2012).

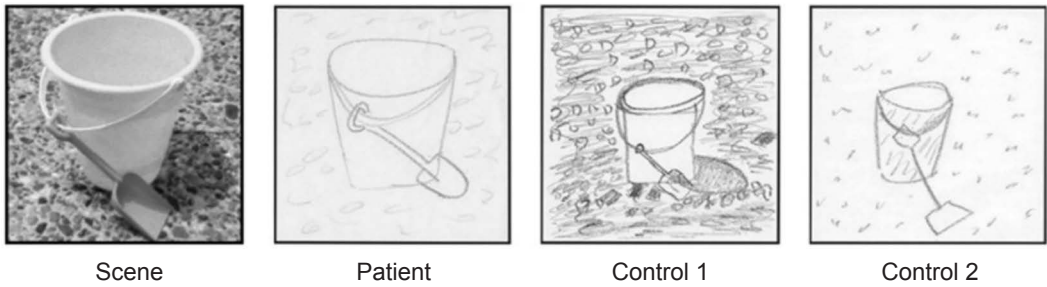


Figure 2.

The results showed that the patients were indeed more precise than the controls. Figure 2 shows an example from one of the several tests that confirmed this prediction. The patient and the controls are equally accurate at depicting the scene (a bucket and spade against a background of pebbles). However, the controls have expanded the boundary, showing a relatively greater area of the pebbles than was present in the original scene.

The hippocampus as a complex structure

The hippocampus does not act on its own. Eleanor had shown that processes like navigation and scene construction depend on specific brain regions interacting with the hippocampus. She also recognised that the hippocampus itself is not a unitary structure. It contains several subfields which differ in their connectivity with other brain regions. Eleanor initiated a series of studies aimed at identifying these components and specifying their cognitive functions. Once again some of her evidence came from patients with brain damage. For example, some patients with bilateral hippocampal damage have no problems with spatial navigation, but have a clear deficit in imagining scenes.²⁸ A subsequent imaging study²⁹ confirmed that scene construction was associated particularly with activity in the anterior hippocampus, while visuo-spatial processes and navigation were more associated with the posterior hippocampus. However, as Eleanor noted, these functions are not completely segregated. For instance, although the posterior hippocampus responds more strongly to visual perception of real scenes than the imagination of scenes, there is also evidence that it is engaged by imagination and recall.

²⁸ Zeidman & Maguire (2016).

²⁹ Dalton *et al.* (2018).

To advance such brain imaging studies further, it was essential to be able to identify the various subfields of which the hippocampus is composed. One of the last papers that Eleanor published³⁰ provided automated protocols for delineating six hippocampal subfields using both 3 Tesla and 7 Tesla magnetic resonance imaging data. It was typical of Eleanor that these protocols were made freely available for all to use.

Eleanor's interest in cutting-edge technology never dimmed. In the last few years of her life, she published a series of papers concerned with the development of Optically Pumped Magnetometry (OPM)³¹ – a new non-invasive method for measuring brain activity that has many advantages over other existing methods. In particular, it works with freely moving participants. This obviously had great appeal for Eleanor since free movement scanning would enable brain activity to be captured during navigation in real, as opposed to virtual reality. Eleanor did much to optimise this measurement technique for use with free movement. She was instrumental in securing funding from the Wellcome Trust to establish a Discovery Research Platform for Naturalistic Neuroimaging at UCL, because she believed passionately in removing any barriers to the adoption of experimental procedures as close to real life as possible. Sadly, she did not live to be able to use the Platform or to see others benefit from doing so.

Appreciation

In was not just on our understanding of the brain that Eleanor had an impact. She also had a major impact on her fellow researchers' lives. She had a magical ability to encourage the people who worked with her. Part of the magic came from her passion for discovery. She never ceased to be excited when new results came in and just loved puzzling over them. This passion rubbed off on her colleagues and students. She also gave up a lot of her time to help her students to really think, that is to think as scientists, not just to churn out articles. Eleanor lived for her work, but rather than putting others off, her driving force also excited her colleagues and students and enabled them to keep up momentum. Eleanor was kind and caring. She appreciated everyone from senior collaborators to visiting students and technical staff.

Eleanor was particularly keen to encourage and support women in science. Using her Royal Society Rosalind Franklin award, she inspired thousands of London school children by developing an essay competition for them to write about a famous female scientist. It would be interesting to know how many of these essays were about Eleanor herself. Her colleagues frequently had the pleasure of witnessing groups of A-level

³⁰Hickling *et al.* (2024).

³¹Seymour *et al.* (2021).

students visiting the Functional Imaging Lab at UCL who, on discovering that ‘Maguire’ worked there, were reduced to a frenzy of excitement and subsequent awe once she walked into the room.

Beyond science, Eleanor was a lifelong supporter of Crystal Palace Football Club, chosen at a young age because of how pretty she imagined the Crystal Palace would be. She was never discouraged by the lack of prettiness or the difficult times experienced by the Palace.

Eleanor Maguire was a remarkable person. She shaped the neuroscience of memory and also many people’s lives. You can see the evidence in the many heartfelt tributes on the memory wall set up by her friends and colleagues.³² She was elected as a Fellow of the Academy of Medical Sciences in 2011, a Fellow of the Royal Society in 2016, and a Fellow of the British Academy in 2018.

Eleanor Maguire died on 4 January 2025, at the age of 54, after a two-year battle with spinal cancer, which she faced with remarkable fortitude. She continued to work on her projects and interact with her research group to her very last few days. Her legacy continues to impact the field of neuroscience profoundly, offering deeper insights into the intricate workings of human memory and cognition.

Acknowledgements

Many people have helped me put together this account of Eleanor’s life. In particular I would like to thank Anne Maguire, Teresa Burke and Alan Beaton for information about her early life, and Cathy Price, Martina Callaghan and Hugo Spiers for information about her life at the Functional Imaging Laboratory. The quotes from Eleanor come from an interview she gave to *Current Biology* in 2012.

A separate version of this memoir, with minor differences, is published in the *Biographical Memoirs of Fellows of the Royal Society*:

doi.org/10.1098/rsbm.2025.0036

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Note on the author: Christopher D. Frith is Professor Emeritus of Neuropsychology at University College London, and Honorary Research Fellow at the Institute of Philosophy in the Institute of Advance Study in the University of London. He was elected a Fellow of the British Academy in 2008.

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Biographical Memoirs of Fellows of the British Academy (ISSN 2753–6777) are published by The British Academy, 10–11 Carlton House Terrace, London, SW1Y 5AH