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Elected FRS 1989

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The psychologist Anne Treisman dedicated her career to the study of attention and perception, a central concern of cognitive science. While still a graduate student, she modified and reformulated the leading theory of auditory attention. Her discoveries and insights into the role of visual attention in the perception of objects, to which she devoted her subsequent decades of research, have had a lasting influence, not only in experimental psychology but also in vision research, neuroscience and artificial intelligence. In a period of rising interest in the brain, her foundational theories inspired thousands of experiments in her own field and others, and the originality and precision of her experimental design confirmed the continued relevance of behavioural research to the scientific enterprise. Treisman’s accomplishments were recognized by the National Academy of Sciences in the USA in 1994 and by the American Academy of Arts and Sciences in 1995. In 1996, she became the first psychologist to win the Golden Brain Award. She received the University of Louisville Grawemeyer Award in Psychology in 2009, and was awarded the National Medal of Science by President Barack Obama at a White House ceremony in 2013.

FAMILY BACKGROUND AND EARLY YEARS

Anne Marie Treisman was born Anne Marie Taylor on 27 February 1935, in Wakefield, England. Her mother, Suzanne Touren, was French, and her father, Percy Taylor, was English. Her mother’s father, brother and nephew were all physics teachers in Paris, and her maternal great-great-grandfather had been, according to his memoir, a soldier in Napoleon’s army whose many adventures included being shipwrecked in Africa while on an expedition to put down Toussaint L’Ouverture’s rebellion in Haiti. Anne’s paternal grandmother came from

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Lidgate, in Suffolk, and had spent years working as a nanny for the family of an Italian count and novelist, Alberto Denti di Piraino. Back in England, after her husband died young, she opened a boarding house for young women from abroad. When Anne’s mother, who had studied law at the Sorbonne, travelled to England to improve her English, she stayed at the boarding house and met Percy.

Percy, who had read politics, philosophy and economics at Oxford before working for a diploma in education, was offered a position in education administration in Wakefield, a mining town in Yorkshire, and that was where he and Suzanne started their married life and where Anne was born. When Anne was five, he was appointed chief education officer for the Medway towns—Rochester, Chatham and Gillingham—in Kent. Soon afterward, the Second World War began. Early in the war, Anne, her mother and her younger sister, Janet, were evacuated to Scotland, where they stayed, together with several other children and mothers, in a large country house near Oban that was owned by a friend of Percy’s. When the separation proved too difficult, they returned to Kent and spent the rest of the war there. Their house was on the path of the V1 flying bombs—or ‘doodlebugs’—heading for London, and barrage balloons, meant to down the doodlebugs before they reached their destination, floated just beyond the garden. Anne’s life was filled with reminders of the war—air raids, blackouts, gas masks at school, ration books, dried eggs, ‘bananas’ made from parsnips and banana essence, and whale meat. She picked rose hips and blackberries, for vitamin C, and mushrooms and ripening wheat in the local fields. She attended the village school, where the headmaster had seven canes of different thicknesses with which he kept order; the worst punishment Anne received, however, was to have to write out a hundred times ‘I will not be late’.

In 1945, when Anne was 11, her father was promoted to become head of the state education system in Reading, Berkshire, where he developed a kind of comprehensive school system, introduced continuing technical education and integrated instruction for the partially deaf into the life of a normal school, among other innovations. Anne attended Kendrick School, a grammar school for girls, where the day started with prayers and a hymn (figure 1 shows her in these years). When, at age 15, she had to choose three subjects to pursue for her A levels, she initially chose the sciences, but her father, worried that she would grow up with no culture, persuaded her to switch to French, Latin and history. She dropped mathematics and science entirely for her last two years of high school. Kendrick School had not sent any students to Oxford or Cambridge for many years, and the teachers feared that the Oxbridge standards were out of reach, but Percy, who had happy memories of his student days at Oxford, encouraged Anne to try. She was accepted and chose Cambridge, becoming a student at the women’s college, Newnham, where she read modern languages. In the 1950s one still needed ration cards for food and for coal. Anne enjoyed sharing coal with friends and spent evenings talking and gossiping in one another’s rooms. She joined a number of clubs, including the Folk Song Society, the Newnham Orchestra, in which she played the violin, a choir and an acting society.

She received a starred first in the modern languages tripos and, thinking that she would need to earn her living, applied for a job teaching French at Oxford High School, but she was turned down. In the meantime, Cambridge offered her a research fellowship to work towards a doctoral degree in French literature. Anne asked if she could instead use the fellowship money to do a second undergraduate degree, in psychology. Her French supervisors were horrified. She remembered one of them saying, ‘But that’s all about rats in mazes!’, but her request was granted.
Anne embarked on her studies in psychology in 1956, at a time of rapid change in the discipline: behaviourism and learning theory were fading and the ‘cognitive revolution’ had begun. Many psychologists were drawn to a new view of the mind as an information-processing symbolic system, and the computer was beginning to replace the telephone switchboard as the dominant metaphor for the brain. Richard Gregory was assigned to be Anne’s supervisor. He suggested that she read about information theory and vision, and he showed her the experiments that he was working on. In one, he had subjects look at a face mask from the inside. If the subject was stationary, the concave mask was usually seen as if it were a normal convex face. Gregory’s explanation was that the strong visual bias favouring seeing a normal face, rather than a hollow mask, reflected the effect of top-down knowledge on perception. As soon as one moved one’s own head and eyes, however, the mask became concave again. Anne and Gregory tried out several of the other illusions and perceptual effects that are described in Gregory’s first book, *Eye and brain* (1956). Gregory was a wonderful teacher, but not a conscientious one. If Anne produced an essay that did not involve perception, he would soon say: ‘That sounds fine. Would you like to try out an experiment I just thought up?’ Nevertheless, he found her so consistently sharp in her responses that he nicknamed her ‘Needle’.

There were 12 undergraduates reading psychology at Cambridge that year (including John Morton, who went on to propose the logogen theory of reading, and Pat Rabbitt, who did great work on skills). Some of the lectures, those by Alan Watson, for example, were still about behaviourism and rats, and Anne did find them interesting, though less inspiring than
those by Gregory or by Oliver Zangwill, one of the early founders of neuropsychology. There was also a series, by Alan Welford, on what were the beginnings of cognitive psychology, and C. G. Grindley lectured on perception.

Once Anne had her Bachelor of Arts degree, she thought she might become a clinical psychologist, but Gregory persuaded her to stay in research, arguing that she could not help people unless she understood the mind. She was again offered a scholarship to do research, this time at Oxford, so she moved there. The requirements for a Doctor of Philosophy degree at Oxford were minimal at that time. There were no lectures for graduate students, no exams and no duties, except to produce a thesis at the end of three or four years. Anne attended department seminars, and listened to Tony Deutsch and Stuart Sutherland argue vehemently about their models of rat learning and octopus perception and about what psychology ought to be. These discussions had a real influence on her by illustrating the power of simple theoretical models to explain perception and behaviour in animals.

On arrival in Oxford, new graduate students were free to pick a topic for their research. Still considering doing something clinical, with the idea of helping patients, Anne asked her advisor, Carolus Oldfield, for suggestions; he proposed that she look at aphasic patients, perhaps using a framework put forward by Colin Cherry in his book *On human communication* (1957). After that, she was, for the most part, left to her own devices. Oldfield was quite shy, and so was she. For several years they would pass each other in the corridors, he would ask how things were going and she would say ‘Fine, thank you’. She was hardly working alone, however, as she belonged to a group of remarkable graduate students. In 1960, she married Michel Treisman, who was a fellow graduate student and, eventually, her colleague in Oxford’s Psychology Department. Figure 2 shows Anne and Michel Treisman around the time of their engagement.

Her most important professional connection was with Neville Moray, with whom she maintained a friendly competition, the goal of which was to improve on the then-dominant filter theory of attention, which Donald Broadbent (FRS 1968) had formulated in 1958 in his book *Perception and communication*—one of the founding documents of cognitive psychology. Broadbent’s main research paradigm used dichotic listening tasks, in which different messages are presented concurrently to the two ears. Participants in the experiment are instructed to focus their attention on one channel and ignore the other, or to divide attention between the two channels and, say, press a key whenever they hear a target word in either ear. Filter theory was developed to explain the observation that participants instructed to listen to a message in one ear later remember little or nothing about the message that was presented to the other ear—in some cases, not even what language it was spoken in. On the other hand, any unusual sound or change in the pitch of the voice on the neglected ear was always noticed and attracted attention, interfering with the performance of the primary task. Broadbent suggested that a filter selects an attended channel defined by some salient physical characteristic (physical location or pitch) and that stimuli that arrive on another channel are held very briefly in sensory storage, but are blocked from perceptual analysis and from consciousness.

Anne used the dichotic listening paradigm in many of her early experiments, often presenting participants with two different passages from Joseph Conrad’s novel *Lord Jim*, which she recorded herself, usually with the instruction to shadow (immediately repeat) the message presented to one ear. She invented many ingenious variations on this paradigm to
test numerous specific hypotheses. In her first publication on the subject (1), she demonstrated that, contrary to a basic assumption of filter theory, the message in the rejected ear is, at least to some extent, analysed as speech. To make that point, she occasionally switched messages from one ear to the other, usually at a point of high redundancy in the shadowed message. In a substantial number of instances, participants followed the attended message into the incorrect ear for one or two words before reverting to the designated ear. Most of the subjects were unaware of their transition errors. Anne’s results demonstrate that continuity of meaning can briefly overcome the effect of channel selection in determining the subject’s shadowing response.

Anne offered a modified version of filter theory in which filtering is not all-or-none; the rejected message is merely attenuated, not eradicated. A verbal message activates hypothetical ‘dictionary units’ in memory, each of which has a threshold that must be exceeded for perception to occur. The threshold is temporarily lowered for a word that the context makes probable, and permanently lowered for highly significant stimuli, such as one’s name. The modified ‘filter-attenuation theory’ could account for all the evidence then available, including the observation already published by Moray (1959) that people frequently recognize their own name when it appears in the rejected message. Broadbent formally accepted this major revision of his original theory, in an unusually gracious concession article, which detailed both the evidence that Anne had collected (he also cited an important supporting experiment by Moray) and her theory (Broadbent & Gregory 1963). Since that time, the label ‘filter theory’ has almost always referred to Anne’s version. This was quite an achievement for a student who was still two years from completing her graduate work.
Feature integration theory

Anne’s dissertation, completed in 1962, was exceptional in its combination of creativity and rigor, and it was certainly among the most important doctoral research in the history of cognitive psychology. The 240-page thesis, titled ‘Attention and speech’, reported 14 experiments, most of which she later published in 11 articles. There were two strands in the work: some studies focused on selective attention, others on the role of context and sequential probabilities in the processing of language, in the spirit of information theory.

Anne was offered a position in the Medical Research Council’s psycholinguistics research unit at Oxford, as well as a teaching position at St Anne’s College. The first of her four children, Jessica, was born in 1963 and the second, Daniel, in 1964. Rather than take time off work when Jessica was born, she took her to work with her. Because of her research on auditory attention, she had a soundproof cubicle in her office and sometimes found it useful when coping with a fractious baby.

In 1966, she was invited to deliver a lecture tour at major American universities from coast to coast. Travelling with Michel, her mother and her two children, she received red-carpet treatment everywhere. In Cambridge, Massachusetts, her colloquium was organized jointly by the psychology departments of Harvard and MIT, and she lectured in a large hall packed with admiring listeners. This level of recognition for someone only a few years out of graduate training was as unusual then as it would be now. Anne was a professional star, but the status had no effect on her behaviour: she remained calm and modest, assertive without a hint of arrogance in her presentations or in the questions she raised after others’ talks. This manner did not change throughout her career.

She and Michel spent the academic year of 1966–67 as visiting scientists at Bell Labs in New Jersey. The psychology department there was excellent, with several brilliant members, including Saul Sternberg, George Sperling, Bela Julesz and Charlie Harris. Anne did some work with Sternberg, who was developing his ideas about using additive effects in reaction time to infer independent processes (Sternberg 1969). She and Michel lived in Morristown, with Anne’s mother there for much of the year to help with the children. They experienced their first Thanksgiving dinner and also had the shock of driving through the race riots in Newark. After returning to Oxford in 1967, Anne was appointed to a lectureship in the psychology department. In 1968 her third child, Stephen, who had Down’s Syndrome, was born and, in 1970, her fourth arrived, Deborah.

In 1969, Anne published an article in Psychological Review that offered a general framework for the study of focused and divided attention (3). Two observations were central to the new theory: (i) people can easily focus their attention on one object or event (e.g. the voice on the right), but have great difficulty dividing their attention between two inputs; (ii) people can easily divide their attention between the various features of an object, but have great difficulty focusing on one feature and ignoring the others. In a major departure from filter theory, she concluded that divided attention and parallel processing are possible for two simultaneous inputs, but only if they do not reach the same analyser. Serial processing is mandatory, however, whenever a single analyser must operate on two inputs. An important implication of this new theory concerned divided attention: unlike filter theory, Anne’s analyser theory permitted parallel processing of information presented to different modalities. Indeed, several of her publications in that period dealt with the possibilities and limitations of divided attention.
In that article, Anne posed a question that would become more important to her, that of ‘how the outputs of analysers are recombined and in particular how they are correctly related to a common source or to different sources. For example, how does one know that it is the ‘H’ that is large and red while the ‘G’ is small and black and not some other combination?’ This was an early formulation of the ‘binding problem’ that her next theory proposed to solve. It also marks the transition from audition to vision as the main focus of her research.

Randolph Blake, a renowned expert on binocular rivalry and stereopsis, has suggested that Anne’s interest in vision and features was manifest much earlier, in an isolated study that she carried out as a graduate student. She discovered in a lab closet an old apparatus called a stereoscope that delivers different pictures to the two eyes. Depending on the relationship between the two pictures, the apparatus may produce stereopsis (a single object seen in three-dimensional depth) or rivalry (a fluctuating mix of the elements presented to the two eyes). Anne engaged in an exploration of binocular vision that was both playful and insightful. Among many other variations, she presented to the two eyes images of circles in different colours. She found that some of her patterns produced the impression of a single fused circle seen in three-dimensional depth, which displayed striking rivalry of colour. She reported her findings and her speculations about the separate representations of shape and colour in an article, published in 1962, which attracted relatively little attention at the time (2). About 40 years later, however, and much to her surprised delight, she heard from Blake that her article had been very much ahead of its time in its insights about stereopsis and about the separate neural representations of shape and colour that could simultaneously produce fusion and rivalry. He also noted that her 1962 thoughts on the processing of separate features were a prophetic portent of her most important work, on the processing and integration of features of perception (Blake 2012). In 2018, Blake remarked that ‘reading her paper today, one might wonder whether Anne’s talents included clairvoyance, for as a graduate student she seemed to anticipate major themes that have defined ideas that have subsequently emerged in the field of visual science’.

One of the many differences between vision and audition is that search is a more natural activity in vision. A listener can be instructed to wait passively for a target—say, a number in a stream of words—and to respond when the target is detected. In contrast, an observer can be shown a complex visual array and instructed to search actively for a target—say, a red ‘H’ in a field of variously coloured letters. Therefore, some discoveries about attention can be made only with visual stimuli. Sometime in the 1970s, Anne began to investigate visual search. The first participants in her research were her children. A summer visitor would find Anne in her garden, on North Hinksey Lane in Oxford, with a stack of white cards and an array of coloured pencils. She would fill a card with coloured letters, then call her children, who were playing nearby, and ask them to find a particular letter. Some targets were much harder to find than others, and that was the start of feature integration theory (FIT).

The features that are ‘integrated’ in FIT are basic visual properties, including colour, size and orientation. These were the subject of much study in the 1970s. A picture was emerging of a visual system that deconstructed the world into its component features as an early step toward the construction of a coherent perception. But this posed a problem. If different aspects of the visual world were processed separately, how were they integrated into coherent perceptual objects? The image of a banana, formed on the retina, might be curved and yellow with a specific size. It might have small dark speckles on its skin. If the early visual system took the image apart into those basic features, how were those features then reintegrated into
a perceived banana? In the jargon of the field, how were the features *bound* into a coherent object representation (15)?

The simplest answer to the binding problem is that the banana is seen as curved and yellow because curved and yellow features happen at the same place in the visual field. Anne’s young children provided pilot data for a project that undermined this simple theory. Imagine a piece of paper showing a collection of red (medium-grey) ‘T’s and green (black) ‘X’s. Figure 3 can serve as a demonstration. Suppose you are instructed to find a blue (light-grey) ‘O’ and a red (medium-grey) ‘X’ in this display. You will find, as Anne’s children did, that the blue (light-grey) ‘O’ is much easier to find, because it has two distinctive features: its shape and its colour are both unique in the display. In contrast, the red (medium-grey) ‘X’ differs from the background only in the combination of features that are shared by other items in the display. To detect it, the observer must bind together this *conjunction* of two basic features.

Anne had observed erroneous conjunctions of features in her auditory research, where, for example, two synchronized words presented to the two ears—‘lack’ and ‘back’—could be combined and heard as ‘black’. She speculated that some process was needed to glue together features that belonged together, and to prevent such illusory conjunctions from forming.

Moving from her garden to the laboratory, Anne obtained more robust measures of the difference between feature search and conjunction search. In the lab, she recorded her participants’ response times (RTs) and their accuracy as a function of the task (feature or conjunction search) and of the number of items in the image (the set size). It is worth mentioning that, in the 1970s, each of these arrays of items was hand-drawn on a white index card and presented in a tachistoscope (a device for presenting visual stimuli for a precise amount of time). The graph in figure 4 (Wolfe *et al.* 1989), redrawn from Treisman and Gelade (1980), shows what she found (5). The ability to detect a unique colour or shape showed very little dependence on the number of items in the display. The time required to detect the presence of a conjunction of colour and shape, however, increased steeply with set size. This was a discovery: features ‘popped out’ of the display, but conjunctions did not.

The RT function was about twice as steep when there was no target in the display. This pattern of a linear increase in RT with set size and double the slope on target-absent trials was consistent with a ‘serial, self-terminating’ search through the display. In a serial search, observers process one item after the other. With N items in a target-present display, observers might get lucky and find that the first examined item was the target. Or they might be unlucky...
Figure 4. Response time as a function of set size with targets defined by a single feature (colour, shape) or by a conjunction (5). Drawn by Jeremy Wolfe, from Figure 1 in (5); reproduced with permission. (Online version in colour.)

and find the target only after examining every other item in the display. On average, across many examples, observers would need to examine \((N + 1)/2\) items in a display before finding the target. When the target was absent, observers would need to reject all \(N\) items, one after the other. As \(N\) increased, the increase in RT would be twice as great for target-absent trials as for target-present. That explains why the slopes of RT \(\times\) set-size functions are twice as steep for the target-absent trials. The data for the detection of simple features suggested that all items could be processed ‘in parallel’, with the odd item registered quickly regardless of the number of distractor items present in the display.

Figure 5 provides another convincing demonstration of the difference between features and conjunctions. It is immediately clear that the upper-left quadrant is different from its neighbours because of the presence of a unique colour. The unique shape (square) and size (small) features in the upper-right quadrant clearly separate it from the other quadrants. There is no such perceptual border between the lower-left and the lower-right quadrants, even though every item in the lower-left is different from every item in the lower-right. The ‘texture segmentation’ seen in this figure shows feature integration theory’s insight into the nature of our ‘preattentive’ visual experience. When we first encounter a scene, the regions and surfaces that make up our perceptual experience are those that differ from one another in their basic features. Later in her career, Anne was a leader in the study of our ability to perceive the statistical mix of features (for instance, what is the average size of these items?) and of our ability to extract meaning from those statistics even before attention permits the binding and recognition of specific objects (18, 21).

Anne published her preliminary findings on feature integration theory in 1977 (4), in volume VI of Attention and performance, a collection of the papers presented in an annual meeting that brought together the main researchers in the field—a group in which she was recognized as quietly dominant. In 1980, she published the landmark article that reported feature integration theory and a large quantity of evidence to support it (5). That article is the most influential of Anne’s contributions. In July of 2019, Google Scholar showed it as having
Figure 5. Texture segmentation. The top quadrant stands out because it is distinguished from its neighbours by a feature. The other quadrants are distinguished from one another by conjunctions of features and do not stand out. (Drawn by Jeremy Wolfe). (Online version in colour.)

received almost 13 000 citations. Ten more of her papers on the topic have been cited more than a thousand times each.

THE VANCOUVER YEARS, 1978–1986

Anne and Michel Treisman divorced in 1976, and in 1978, after a year with Daniel Kahneman (known as Danny) at the Center for Advanced Study in the Behavioral Sciences at Stanford University, she remarried. Having fallen in love with the beauty of Vancouver on a previous visit, Anne and Danny chose to join the psychology department at the University of British Columbia and set up a laboratory there, in which they pursued studies of attention, both jointly and separately. Figure 6 shows Anne with some of the graduate students in the Treisman-Kahneman lab in the early 1980s. The professional gossip at the time was that, in moving to British Columbia, the couple had opted for lifestyle over work, but the Vancouver period was one of the most productive in Anne’s career.

The FIT project exemplifies Anne’s approach to research: insightful ideas inspired diverse, clever paradigms that supported a core theory. She rarely published papers that reported on just one study. The original FIT paper details nine experiments. Table 2 of her follow-up on the phenomenon of ‘search asymmetries’ in feature-search tasks lists 28 conditions that could be grouped into 15 experiments (11). That combination of insight and rigor has made FIT an important touchstone of visual-attention research for nearly 40 years, and a rich source of productive controversy.

FIT inspired waves of research and not all the results supported the theory as Anne had articulated it in 1980. In particular, reports of conditions in which search for conjunctions was parallel challenged one of the main tenets of Anne’s theory. The inference of serial processes from RT data was also questioned. Reading the critiques (Duncan & Humphreys 1989; Wolfe 1994), one is impressed by the respect that Anne’s critics express for her achievement. She was also unusually gracious toward and supportive of her critics, especially the younger ones, though being gracious and supportive did not mean that she was going to abandon her own
ideas. She continued to argue for the core FIT concepts even as she adapted her theory when the data demanded it. For example, the original FIT held that all conjunction searches would be serial and self-terminating. To accommodate data from several labs showing that conjunction search could be much more efficient than the original FIT had predicted, Anne published ‘Conjunction search revisited’ (12), which proposed a modification to FIT that permitted all items having some known distractor property to be inhibited. However, she continued to defend the basic two-stage FIT architecture, with a parallel front-end processing of a set of basic features followed by an attentional bottleneck that allowed for the binding and recognition of one or, perhaps, a few objects at one time.

Seminal articles that open a new field often remain more famous than even their most successful critiques—and vastly more famous than subsequent corrections by their authors; so it was with FIT. In 2018, more than 20 years after the publication of important alternatives to FIT (Desimone & Duncan 1995; Wolfe 1994), the original source was cited more than three times as often as the critiques and about 10 times as often as Anne’s revision of her theory. It was a matter of some annoyance to her that people continued to raise the same difficulties with the original theory after she had modified it to accommodate them (11, 12).

One of the reasons for FIT’s longevity is the number of surprising and interesting discoveries to which it led. Anne published two important articles on search asymmetries, in which she showed that ‘search rate for a target among distractors may vary dramatically depending on which stimulus plays the role of target and which that of distractor’ (9). She
reported pronounced asymmetries in the ease of finding large lines in a display of short lines (easy) or vice-versa (difficult), bent lines in an array of straight lines (easy), the letter Q in a field of Os (easy). Anne showed that the presence of terminators at the end of lines is a feature, while intactness (the absence of intersecting lines) is not. She also confirmed a direct prediction of FIT: that searching for the absence of a feature is more difficult than searching for its presence (9, 11). These articles greatly advanced the understanding of the basic vocabulary of visual features.

Another line of research involved what Anne called ‘illusory conjunctions’. You have probably already had a look at the shapes in figure 7. Cover it up with your hand and ask yourself if you saw a red (black) plus, a purple (white) horizontal bar, and/or a yellow (textured) triangle. If you said ‘yes’ to the red (black) plus, you are correct. It is present. You are unlikely to think that you saw a purple (white) horizontal bar because there are no horizontal bars of any sort in the image. The yellow (textured) triangle is the interesting case. If you thought that you saw a yellow (textured) triangle, you experienced an illusory conjunction. FIT proposed that attention was required to bind features like colour, texture and shape. In the absence of adequate attention, Anne found that observers experienced failures of binding. There are yellow (textured) items in the image, and there is a triangle, but a yellow (textured) triangle is a misbinding of those features. In the laboratory, illusory conjunctions became a research tool (6). The paradigm was picked up in many labs. ‘Illusory conjunction’ is found in the titles of more than 70 papers in the Web of Science database. (More than 225 titles include ‘feature integration’.)

During the Vancouver years, Anne collaborated with Danny on another project that she later integrated with FIT. They developed the notion of an ‘object file’, an episodic representation of a perceived object, which is maintained by spatial and temporal continuity even when its interpretation changes (8, 13). The name ‘object file’ was chosen in analogy to a police file, in which details on a criminal are entered into a file as a case develops, even as the criminal continues to move about and change aliases. In her 1988 Bartlett Lecture, Anne introduced the idea with a vivid example: ‘A distant aeroplane retains its continuity as a single perceptual object, even when we see it flap its wings and alight on a nearby tree, thus forcing us to change the label we initially assigned’ (10). The processing and the retention of sensory data are both facilitated when they are assigned to a single object file.

Anne and Danny presented two consecutive lectures at the 1983 meeting of the Psychonomic Society on what they called a ‘re-viewing effect’. Figure 8 illustrates one
of the paradigms they used. The preview field contains two letters and is presented for a brief duration (<1 s). When it is removed, two letters immediately appear in one of four possible positions (up or down, left or right). The display produces a pronounced impression of apparent movement of two objects. The participant’s task is to name the target letter as quickly as possible: the correct responses are B, J and D in the three panels. The naming time was shorter by about 30 ms when the target letter was pre-viewed in the same object (top panel) than when it was not. This ‘object-specific re-viewing effect’ demonstrated a novel type of priming, which was confirmed in multiple experiments with different displays.
Although the results were reported in full in 1983, they were not published until 1992, because Anne and Danny could not agree on the theoretical interpretation of object files. Anne believed that object files were set up by the same operation of attention that integrates features, while Danny argued that they were formed pre-attentively. The couple attempted repeatedly to formulate a critical experiment that would determine the correct interpretation. Time and again, they had the experience of both agreeing that the outcome of a planned experiment would determine a winner, only to discover, once the results were known, that the ‘loser’ could now see a design flaw that made the experiment inconclusive after all. They never fully resolved the different theories and the experience shattered their belief in the feasibility of critical experiments, at least in psychology. Figure 9 shows Anne and Danny Kahneman in 1984.

**The Berkeley years, 1986–1993**

In 1986, Anne and Danny moved to the University of California at Berkeley, where they maintained a lab together, dubbed the Attention Lab. The joint lab was a lively place, at the centre of which a pair of plain light-blue loveseats faced each other across a coffee table. Although Anne had an official office down the hall, she was usually found on the ‘blue couch’, with a pile of papers in front of her. Having raised four children, she had little trouble concentrating as undergraduate research assistants, grad students and postdocs bustled around her. The lab population had a diverse mixture of intellectual interests, from perception and attention to decision making and marketing, which made for many stimulating conversations. There was also a wide age range, from newly minted college graduates to adults returning to grad school after careers in other fields. This diversity helped the lab gel into a kind of academic family, with older, more experienced students mentoring younger ones.
(Former members of the Attention Lab prided themselves on that identity and maintained frequent contact for decades.) The fame of FIT was growing rapidly during the 1980s. Anne was frequently invited to present her evolving version of the theory to different audiences, including neuroscientists and computer scientists, and her publications during the Berkeley years reflected these demands.

In an undated interview with the British Psychological Society, Anne noted that her one regret was ‘not having any background in neuroscience or mathematics’. She was well-read in the neuroscientific literature, and the opening paragraph of her seminal paper on feature integration theory cites Semir Zeki’s account of the neurophysiological separation of feature channels in the visual cortex (Zeki 1978). Her experimental research, however, had been exclusively behavioural. This began to change during her years in Berkeley, thanks to the friendship and collaboration she developed with Lynn Robertson, a cognitive neuropsychologist who specialized in the study of disturbances of spatial vision after brain injury.

The collaboration led to several research papers that relied on neurological syndromes to explore the nature of attention. For example, patients with parietal lobe lesions sometimes display unilateral neglect, a failure to orient to stimuli on one side of space. A patient with damage in the left hemisphere might leave the right side of his face unshaven, or the right side of his dinner plate uneaten. Robertson and her colleagues had established that neglect was a disorder of spatial attention (Eglin et al. 1989). Anne’s visual search paradigm made it possible to show that perceptual grouping occurs even in the neglected field—a clear demonstration that grouping is pre-attentive.

Another line of research, conducted with Robertson and her student Stacia Friedman-Hill (14), concerned the patient ‘RM’, who suffered from Balint’s syndrome, named after the neurologist who reported the first case in 1909. The syndrome, which is the result of bilateral parietal lobe lesions, leaves the patient ‘functionally blind’, able to see only one object at a time, even when many are present in the visual field. Objects go in and out of awareness uncontrollably, their locations unknown. A Balint’s patient cannot tell if a spot is at the top or the bottom or the left or the right of a screen. Body space and spatial understanding remain intact, but are not sufficient to support the activities of daily living. Anne and Robertson received a National Science Foundation grant to study RM.

FIT offered an elegant description of the difficulties of Balint’s patients. A central concept of FIT is the ‘master map of locations’, which is scanned by attention to bind objects. The spatial problems observed in Balint’s patients indicate the loss of this master map. The theory predicts that the patients should be able to detect the presence of a particular feature (a shape, a colour) in a multi-item display—the feature would ‘pop out’—but that its location would be unknown. Binding features (e.g. green and circle) requires spatial selection in the master map of locations, which is not available to Balint’s patients. This prediction was supported by several studies (14, 16). The theory also predicts that Balint’s patients should be highly prone to illusory conjunctions. Illusory conjunctions occur in normal adults, but they are relatively rare and restricted to very brief exposures of 200 ms or less (7). Without a functioning master map of locations, however, illusory conjunctions should be found even in prolonged exposures. As predicted, the rate of illusory conjunctions in Balint’s patients was very high (close to 30%)—even when the exposure was as long as 10 s. These results provided a novel form of support for Anne’s theory and demonstrated that the binding problem was more than a laboratory curiosity.
The results also provided new insights into the effect of spatial deficits on object perception. Although full spatial loss is rare in neurological patients, partial loss is common. Before Anne’s research, it was not part of neurological testing to ask Balint’s patients the colour, size, orientation, etc. of objects they reported seeing; examiners simply assumed that if an object was reported (say, a dog) it was perceived with its features intact (hair texture, colour, motion, etc.). The features of one object were not expected to float to other objects, but they do (Robertson 2003).

Anne engaged enthusiastically in the project. With her typical hands-on approach to research, she spent many hours testing the patient with Robertson, often driving to and from his home with all the testing apparatus in tow. She sorted through data on the way home, while talking about the theoretical significance of the observations of the day. It all had to fit together, and she was not afraid to change her mind if the data suggested that her thinking was weak or wrong. She was the ultimate integrator. During these trips, Anne would also jot down ideas for more studies. One of those ideas led to the observation that RM perceived familiar objects in their upright, canonical orientation, regardless of their actual orientation in the display. This simple experiment showed that RM’s perception of objects was guided by representations in memory.

THE PRINCETON YEARS, 1993–2010

In 1991–92, Anne and Danny spent a sabbatical year at the Russell Sage Foundation in New York. While they were there, in October 1991, a fire consumed more than 3000 houses in Oakland and Berkeley, including their home in the Berkeley Hills. After a year back in Berkeley, in a new house, they decided to accept an offer from Princeton University, where they stayed for the next 17 years.

During this last phase of her career, Anne worked mostly from her Green Hall office overlooking Washington Road, which she decorated with large, beautiful plants and a striking red couch. Her students of that period report the experience of entering her office with a sense of awe only to be greeted by Anne’s gentle smile and her characteristic unassuming manner. The lab was small, a couple of graduate students and postdocs at a time, all of whom Anne encouraged, inspired and occasionally worried about. She was again a much-loved motherly mentor.

During these years, Anne investigated how multi-feature objects and their locations are preserved in visual working memory. Two papers showed that attention has similar effects on the perception of objects and on their representation in memory (17, 23). Anne had always recognized the implausibility of the idea that we can perceive the world only by serially scanning each object. When we open our eyes on an unknown picture or scene, objects do not appear to us one at a time, as their features are bound by the serial allocation of local attention. We know a great deal about the scene as soon as we see it. Anne’s interest shifted to this form of widely distributed attention. What do observers see when their attention is spread over the whole display? She tried two ways of answering this question.

With her student, Karla Evans, she replicated and extended a study that had demonstrated that observers were able to detect the presence of animals in natural scenes, even when their attention was directed at another task (Li et al. 2002). Anne wondered whether their performance reflected the detection of disjunctive feature sets, rather than high-level
binding. Evans and Anne presented very rapid strings of images of natural scenes, which occasionally included an animal or a vehicle, and explored what information was available when participants reported one of these targets. They found that participants performed quite well in detecting the presence of target categories, but were often unable to identify or to localize the targets that they had correctly detected, suggesting that detection was based on only partial processing. If we have acquired the ability to detect such features as fur, legs, wings, wheels or windows, we may recognize objects by such features without binding several features together. Detection can be based on one or two features, whereas identification usually requires binding (21).

Guided by her new interest in distributed attention, Anne followed up an important article by Dan Ariely (2001), which suggested that people form an accurate impression of the average size of objects in an array of objects without forming representations of individual objects. With her student, Sang Chul Chong, she explored several parameters of the phenomenon of statistical processing. She found that judgements of average size can be made very fast, without any possibility of serial scanning, and she proposed that statistical processing occurs with distributed, rather than focused, attention. Chong and Anne demonstrated the role of distributed attention in an elegant set of studies in which participants who were concurrently engaged in a task that encouraged a wide distribution of attention made more accurate statistical judgements than when the window was narrow (19, 20, 24). Anne went on to show that average properties are encoded for multiple sets at the same time, although with an accuracy decrement when they are on separate feature dimensions (20, 25). She concluded that statistical processing is a mechanism by which the visual system economically represents sets of objects without overloading focused attention. It was a matter of some satisfaction to
Anne that she had now explored the whole range of spatial attention, from very narrow to very wide (18, 22).

LAST YEARS

After retiring from Princeton in 2010, Anne moved full-time to the apartment on East 10th Street, in New York, that she and Danny had used for years as a weekend pied-à-terre. There, she was able to pursue her love of theatre, dance and opera, and to spend more time with her daughters, Jessica and Deborah, as well as with two of her granddaughters, Deborah’s daughters, Natalya and Imogen. Jessica was, by this time, a professor in the Department of Cell Biology at the Skirball Institute at New York University, and Deborah had become the fiction editor of *The New Yorker* magazine. Anne’s son, Daniel, had become a professor of political science at the University of California Los Angeles, where he lived with his wife and two daughters, Alexandra and Lara; her son, Stephen, was living at Norwood’s Ravenswood Village, in England, an educational and care facility for the learning disabled.

In 2013, Anne was awarded the National Medal of Science, the highest honour in science given by the US government, by President Barack Obama in a White House ceremony that her proud children attended (see figures 10 and 11). The citation acknowledged the ‘enormous impact’ she had had both inside and outside the field of psychology, and noted that ‘her Feature Integration Theory formed the basis for thousands of experiments in cognitive psychology, vision sciences, cognitive science, neuropsychology and cognitive neuroscience’. In an interview with the American Psychological Association, Anne reacted with her usual
modesty: ‘I am very happy that psychology is among the subjects selected for the award, although many other psychologists would be at least as deserving to receive it.’

When she died, on 9 February 2018, at the age of 82, tributes poured in from friends, colleagues, former students and collaborators, even people who had barely known her. Several ex-members of the Berkeley Attention Lab crossed the country to be with her family a week after her death. A tribute was posted by her former student and collaborator, Nancy Kanwisher:

Anne was a huge inspiration to me, indeed to all the cognitive psychologists of my generation. As this group will know, she is responsible for an astonishing number of the foundational discoveries and ideas in our field. But she was also a generous and kind person. . . . Anne had a wry sense of humor that was all the more delightful coming from this otherwise reserved and gracious giant of the field. I remember us ‘kids’ in the lab worrying about the latest attack on feature integration theory, and Anne just responding with a mischievous grin and a sparkle in her eye, saying: ‘Here we go again!’ I remember a starstruck graduate student approaching her at a conference and telling her about their obscure psychophysical finding, and Anne saying: ‘What would you like, my blessing?’ I remember her reporting that when she first moved to California, and one of the very Californian psychologists at Stanford asked her, ‘What do you do for your body?’, she replied ‘I feed it!’ What a huge loss for many of us personally, and for our field.

**APPOINTMENTS**

1963 Medical Research Unit in Psycholinguistics, Oxford
1966 Visiting Research Scientist, Behavioral Sciences Department, Bell Labs, Murray Hill, NJ
1967 Fellow of St Anne’s College, Oxford
1968 University Lecturer in Psychology, University of Oxford
1977–1978 Fellow at the Center for Advanced Study in the Behavioral Sciences, Stanford, CA
1978 Professor of Psychology, University of British Columbia
1984 Fellow of the Canadian Institute for Advanced Research
1986 Professor of Psychology, University of California, Berkeley
1991–1992 Visiting Scholar, Russell Sage Foundation, New York
1993–2010 James S. McDonnell Distinguished University Professor of Psychology, Princeton University

**HONOURS AND AWARDS (SELECTED)**

1979 Society of Experimental Psychologists
1982 Killam Senior Fellowship
1982 James McKeen Cattell Sabbatical Award
1989 Fellow of the Royal Society, London
1990 Howard Crosby Warren Medal of the Society of Experimental Psychologists
1990 Distinguished Scientific Contribution Award of the American Psychological Association
1992 William James Fellow of the American Psychological Society
1994 Foreign Associate, National Academy of Sciences
1999 Member, National Academy of Sciences
Biographical Memoirs

2004 DSc, Honoris Causa, University of British Columbia
2005 Elected to American Philosophical Society
2006 DSc, Honoris Causa, University College, London
2008 George Miller Prize from Cognitive Neuroscience Society
2009 Grawemeyer Award in Psychology
2009 Elected to British Academy
2011 Governing Council of National Academy of Sciences
2013 National Medal of Science, USA
2013 Wiley Prize for Psychology, British Academy

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Author profiles

Daniel Kahneman

Daniel Kahneman is Professor Emeritus of Psychology and Public Affairs at Princeton University. He is best known for his joint research with Amos Tversky in the 1970s on human judgement and decision making and as the author of Thinking, fast and slow (2011). He is a member of the National Academy of Sciences (USA) and other academic societies. He is the recipient of the Nobel Memorial Prize in Economic Sciences (2002) and the National Medal of Freedom (2013).

Deborah Treisman

Deborah Treisman, Anne’s younger daughter, has been the fiction editor of The New Yorker since 2003, and has been on staff at the magazine since 1997. Prior to that she held positions on the editorial staffs of Grand Street, The New York Review of Books, and Harper’s Magazine. She was a co-author, with Walter Hopps, of The dream colony: a life in art (2017). She studied Comparative Literature at the University of California, Berkeley.
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(2) 1960 Binocular rivalry and stereoscopic depth perception. *Q. J. Exp. Psychol.* 14, 23–36.

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