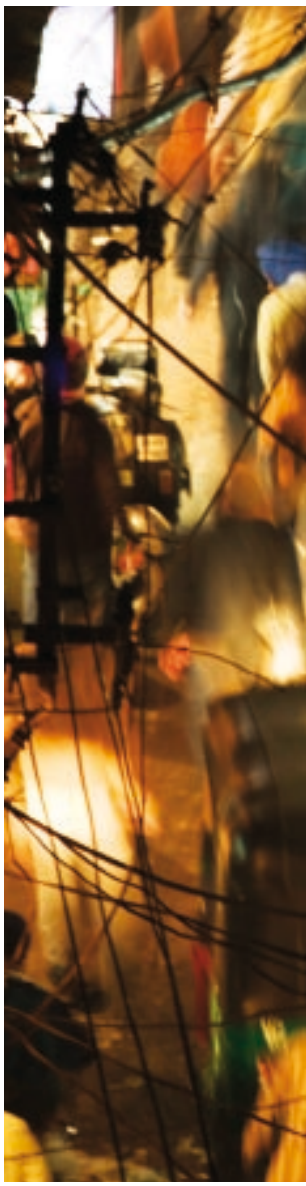
THE 12 PILLARS OF WISDOM

Can we ever understand intelligence? Only by building it up from its component parts, say **Adrian Owen** and **Roger Highfield**



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The ability to process visuospatial information helps shape intelligence

THERE are few more controversial areas of science than the study of intelligence. Its history is littered with disreputable ideas, from phrenology and other pseudoscientific ways of measuring it to flawed attempts to link it to race. Today intelligence remains contentious, not least because there is still no agreement on precisely what the word means.

With no agreed definition, measuring intelligence is fraught with problems. Unlike weight and height, which are unambiguous, there is no absolute measure of intelligence, just as there are no absolute measures of integrity, honesty or physical fitness. But just as it is apparent that some people are physically fitter than others, some people are also smarter than others. And just as there are tests that capture individual differences in physical fitness, we can devise tests that capture differences between individuals' cognitive abilities.

Most intelligence tests are based on performance at an assortment of different types of mental tasks. The most widely used is the intelligence quotient (IQ), now commonly measured using the Wechsler Adult Intelligence Scale. In this test, results from a 90-minute battery of tests of comprehension, vocabulary and arithmetic are combined to derive a final IQ score.

This measure of intelligence does seem to correlate with performance at school and work, so to this extent at least, IQ reflects how smart a person is.

Since the original Weschler test was published in 1955, there have been a number of attempts to systematically break down intelligence to see whether it is best captured by a combination of many independent cognitive abilities, or whether there might be one over-arching performance factor called "generalised intelligence".

The concept of generalised intelligence emerged from the observation that people who do well on one particular mental task, such as mathematical dexterity, tend to do well on other tasks too, such as remembering strings of numbers. In fact they generally get high scores across the board. In 1904, psychologist Charles Spearman suggested that various cognitive tasks are underpinned by a general mental faculty now known as Spearman's factor, or "g".

Research on generalised intelligence suggests that it depends on the use of reasoning strategies to go beyond baseline cognitive performance. For example, in a test of short-term memory based on recalling strings of numbers, smart people often "chunk" the numbers into related groups such as 2,4,6 and 5,7,9. Such strategies do nothing to increase the size of short-term memory but they improve the efficiency with which the contents of memory are organised.

The same goes for visuospatial working memory, the ability that allows you to temporarily hold and manipulate information about objects and places. For example, a chunking strategy enables chess masters to memorise up to 100,000 configurations of chess pieces, and to remember each one much

more accurately than non-expert players.

Yet more than a century after Spearman, generalised intelligence remains contentious, with some psychologists maintaining there is no clear correlation between the ability to carry out different mental tasks.

Now a team at the UK Medical Research Council's Cognition and Brain Sciences Unit in Cambridge, led by one of us (Adrian Owen), wants to probe the question further.

Drawing on 20 years' research, we wanted to find the smallest number of tests to cover the broadest range of cognitive skills that are believed to contribute to intelligence, from memory to planning. We also wanted to explore as much of the brain's anatomy as possible, from the major structures of the cerebral cortex – the outer layer of the brain responsible for higher processes – such as the frontal, temporal and parietal lobes (see diagram, left), to deeper-lying structures.

The result is a set of tests that probe what might be called "the 12 pillars of wisdom". These 12 pillars are outlined on the pages that follow.

As well as laying bare the building blocks of intelligence, there is also a practical aim. Although our approach will never solve the problem of what intelligence is, it could give us fresh insights into generalised intelligence by showing whether there is a correlation between the performance on the 12 tests.

You too can participate in this experiment. On page 43 you will find details of how you can measure your own pillars of wisdom, and get involved in what might be called the ultimate intelligence test.

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1 Visuospatial working memory

When you navigate your way around an unfamiliar environment, you rely on visuospatial working memory. This component of intelligence contributes to many everyday feats, such as judging the trajectory of other vehicles while you are driving and remembering where you parked your car. It relies on storing information about the position of objects in your environment in working (or "short-term") memory and then retrieving it when you need it.

Its importance can be appreciated by imagining what life would be like if you didn't have it. Similar abilities helped our ancestors store and retrieve food, revisit a fruit tree or return to their cave.

Brain region: When people undertake tasks involving visuospatial working memory there is activity in the ventrolateral frontal cortex a few centimetres behind the eyes, particularly in the right hemisphere, and the parietal lobe at the back and on top of the brain.

2 Spatial working memory

Imagine you are hunting for a pot of gold that you know is hidden in one room in a block of 100 apartments. What's the best strategy?

One option would be to search randomly, but that imposes a huge load on working memory because you would have to remember each apartment you have visited. A far smarter plan would be to organise your search, covering all the rooms in one apartment before moving on to the next, and covering all the apartments on one floor before moving on to the next. That way you can always keep track of where you are in the overall search without having to remember each and every apartment that you have already checked.

Brain region: People with frontal-lobe damage find even easy versions of this task taxing. Even if their memory is not impaired, their ability to organise the contents of memory is, suggesting that the frontal lobe is responsible for how we optimise our memory. The posterior parietal lobe is also engaged. ›

3 Focused attention

Read a word and you will automatically hear it pop into your head. This is an example of what is known as an overlearned or prepotent response. It is such a basic reaction that it is hard to inhibit. Doing so takes concentration and attention, which together form the foundations of this pillar of wisdom.

The ability to inhibit prepotent responses can be measured by what is called the Stroop effect. In a typical Stroop test, the reflex is confused by showing, for example, the word "green" written in red ink. The subject then has to name the colour of the ink rather than read out the word.

To measure this pillar of wisdom accurately requires a doubly hard version of the Stroop test in which the subject not only has to name the coloured word but also distinguish between two possible answers: for example, the word "red" written in green ink and the word "green" written in red ink (see below).

Which of the words at the bottom is the same of the colour that the word at the top is written in?

And again

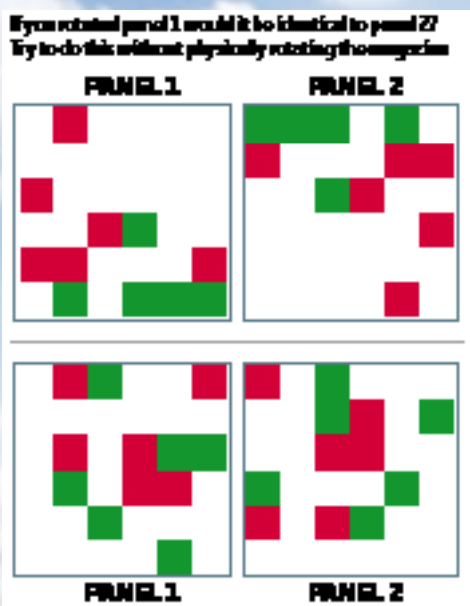
Brain region: This is a complex task that recruits different regions that are simultaneously involved in focused and sustained attention. It is known to involve the right frontal cortex, as people with an injury to this area have problems maintaining attention while performing these tasks. Damage to this area is thought to be responsible for poor concentration in people who have suffered a traumatic brain injury.

4 Mental rotation

When you read a map while navigating, do you need to physically turn it to make sense of your direction or are you able to "mentally rotate" it in your head? This pillar of wisdom is linked to navigation and our ability to see things from a different perspective. It underlies many everyday activities, from finding your way home to recognising familiar objects placed in unusual positions or orientations.

Brain region: Known to depend crucially on the superior parietal cortex, at the back and top of the brain.

If you rotated panel 1 would it be identical to panel 2? Try to do this without physically rotating the computer



5 Visuospatial working memory + strategy

The game called concentration (also known as pairs) begins with a standard pack of playing cards laid face down. On each player's turn, they choose two cards and flip them face-up. If the two cards are of the same value and colour the player wins that pair. If they don't match, the cards are flipped back. The aim of the game is to win as many pairs as possible.

Activities like this, including an online version devised by the MRC Cognition and Brain Sciences Unit team called Monkey Ladder, require not only visuospatial working memory but also an ability to devise and deploy strategies that keep track of cards you have seen.

Brain region: Essentially the same as for pillar 1, but as the demand for more complex storage increases, along with the need to use strategies, broader regions of the frontal and parietal lobes become active – in particular, the large area behind the temples known as the dorsolateral frontal cortex.

PETER CADE/IMAGE BANK/GETTY

6 Paired associate learning

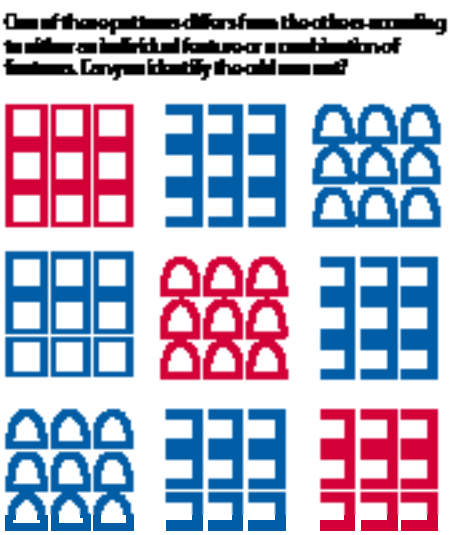
Every day we have to link memories, such as a person with their telephone number. Psychologists call this paired associate learning, as you are required to pair two items in memory. This is essential in many aspects of everyday life, for example when learning a new word, which requires pairing the memory of how it sounds (or what it looks like when written down) with what it means. In short, it enables you to learn the connections between related concepts.

Brain region: Pairings that involve spatial or visual information activate two "streams" or networks of brain regions. The parietal lobes deal with spatial information (the "where" stream) and the outer region of the temporal lobes deals with perception and memory for objects (the "what" stream).

"People who do well at one particular mental task tend to do well on others too"

7 Deductive reasoning

Determining which one of a series of shapes is the odd one out is a classic reasoning test. At its simplest, say when there are five circles and a square, the answer is obvious. But as the variations in shape become more complex, the odd one out can only be identified by considering several aspects of the information at the same time. This relies on a pillar of wisdom known as deductive reasoning.

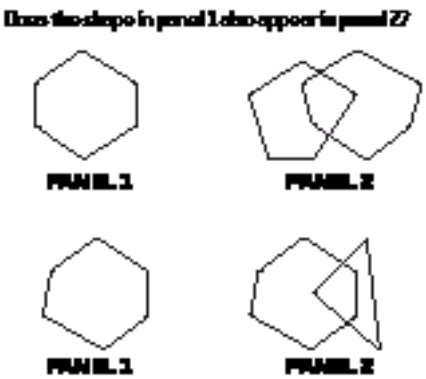


Brain region: Deductive reasoning tests generate a characteristic pattern of activity in the back and outer surface of the frontal lobes, at the intersection between the two hemispheres, and in the middle of the parietal lobe at the back and top of the brain. A recent study of people with damage to some of these brain regions – as a result of a stroke, for example – showed that the extent of the damage was correlated with the degree to which this task was impaired. ›

8 Visuospatial processing

The survival of our ancestors depended on the ability to detect an important shape in a complex background. Think of a lion lurking in long grass, or a ripe fruit hanging from a branch. When you mentally compare complex images with each other you rely on another pillar of wisdom, your brain's visuospatial processing skills. Even in the modern world, this is a useful skill. Imagine being in a burning house, trying to find the key that will open the front door among a huge bunch of keys, as flames threaten to engulf you.

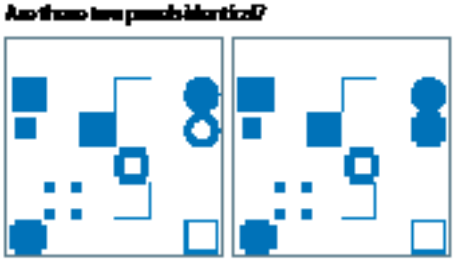
Brain region: Parietal cortex and higher visual areas in the occipital lobe at the back of the brain.



9 Visual attention

Spot-the-difference puzzles are an old favourite in newspapers and magazines, and now appear online too. In the most common form, two subtly different versions of an image are shown side by side, and you have to find differences between them. This is a perceptual task that requires you to concentrate or focus your attention on complex images.

Brain region: Attention to visual features increases the activity in a range of visual areas at the very back and bottom of the brain.



10 Verbal reasoning

If you are told that A is bigger than B and that C is bigger than A, the pillar of wisdom known as verbal reasoning tells you that C must be bigger than B, even though this information is not explicitly stated in the problem. This pillar can be measured by a variant of the Grammatical Reasoning Test developed in 1968 by Alan Baddeley, the former director of the MRC Cognition and Brain Sciences Unit (then called the MRC Applied Psychology Unit).

Brain region: Reasoning tasks activate the dorsolateral frontal cortex, which lies on the outer surface of the frontal lobe about midway between the top and the bottom.

It is useful to be able to spot the predator lurking in the long grass

DAVID J SLATER/WORKBOOK STOCK/GETTY

11 Verbal working memory

"IQ does seem to correlate with performance at school and work"

When you hold a new number in your head as you enter it into your phone, you rely on a pillar of wisdom known as verbal working memory – the ability to store a piece of verbal information for just as long as it is needed. This temporary memory bank allows you to make sense of convoluted sentences used by the likes of lawyers, bureaucrats and the manufacturers of electronic appliances.

Brain region: The ventrolateral areas of the frontal cortex, particularly the left hemisphere. The ventrolateral frontal cortex is crucial for laying down short-term memories, and also for retrieving them when they are needed.

12 Planning

Many activities are made up of a sequence of tasks that must be done in the right order. You have to buy the ingredients of a cake before you bake it; redecoration should take place before a room is carpeted; you need to check you have money before you go shopping. The capacity for such forward thinking can be probed with the Hampshire Tree task, which requires the subject to put a set of balls in the right order using as few moves as possible.

The cognitive processes involved are surprisingly complex. First you must create mental representations of the starting and finishing arrangements of the balls. Then you have to work out how to link these representations, by searching though all possible solutions and evaluating how well they will work. Cognitive planning is at the apex of human achievement: there are very few documented examples of other animals truly planning.

Brain region: The frontal lobe is crucial for planning, as was demonstrated in the 1930s when neurosurgeon Wilder Penfield removed a tumour from his sister's right frontal lobe. This led to a dramatic change in her behaviour: for example, while she remained able to cook individual dishes, she could no longer plan a complete meal. More recently, brain scanning has revealed that planning involves a broad network of regions, including the caudate nuclei near the centre of the brain, the supplementary motor area at the top and in the middle of the brain, posterior parietal regions at the back and top and the cerebellum. ■

TAKE PART IN OUR EXPERIMENT

We would like to invite you to assess 12 facets of the way your brain works using a simple online test that should take around half an hour. The online audience of the Discovery Channel will also be invited to take part.

We hope that by measuring these "12 pillars of wisdom" in a large number of people we will at last be able to put the concept of generalised intelligence to a rigorous test. In the coming months, we will publish an analysis of what we find.

This could help to place the concept of intelligence on a firmer footing as a real attribute of human brain function, not merely a construct that reflects only an individual's skill at completing traditional intelligence tests. More usefully, and controversially, it could eventually help disentangle the effects of genetics, lifestyle and education on intelligence and, in turn, the effects of intelligence on other aspects of our lives. IQ scores are correlated with many aspects of general well-being, including lifespan, presumably reflecting how smart people make better choices about how to conduct their lives.

One thing is for sure: the ingredients of intelligence involve a complex interplay between our genetic make-up and our environment. It is not, as pioneering psychologist Charles Spearman and many of his peers believed, simply the intellectual gifts we inherit from our parents.

You can take part in the ultimate intelligence test at bit.ly/9M6NaP.

ANSWERS
3: RED; RED. **4:** identical; identical. **7:** blue squares (clue: start by eliminating ones that cannot be the odd one out). **8:** no; yes; **9:** no. **12:** move 4 next to 8; move 3 next to 2; move 4 and 3 into position; move 7 into position; move 2 into position (6 moves)