Images of Intellect

Brain scans may colorize intelligence

By BRUCE BOWER

French psychologist Alfred Binet devised the first intelligence test in 1905 to help Parisian educators identify students with learning problems. Soon thereafter, a modified version of Binet's brainchild achieved widespread use by educators in the United States and elsewhere. Psychologists followed suit by emphasizing the study of general intelligence, or g.

In the past decade, a number of researchers have taken issue with the notion of general intelligence, proposing that different types of intelligence exist. Examples include the capacity for generating novel ideas and the ability to reason with numbers. But investigators of all theoretical stripes still follow Binet's lead in relying on mental tests to measure the intellect at work — except for Richard J. Haier.

A neuropsychologist at the University of California, Irvine, Haier travels to the heart of smarts — the brain — and takes pictures of his journey. They may not be Kodak moments, but Haier's color-coded images of thinking brains offer provocative and surprising clues to the nature of intelligence.

"There are lots of mental-test data and very little brain data in this area, but it's hard to come up with theories of intelligence without knowing about brain function," Haier contends.

The Irvine scientist described his latest brain-imaging studies, which have been either accepted at or submitted for publication to various scientific journals, in July at the annual meeting of the American Psychological Society in Washington, D.C.

Haier's research team uses positron emission tomography (PET) scans to measure the rate at which the brain burns up glucose, its primary fuel. Volunteers receive injections of minute, harmless amounts of a radioactively labeled glucose compound that their brain cells absorb; PET scans then chart how hard the brain works as participants grapple with mental tests.

Initial findings indicated that smart brains solve complex problems by conserving energy rather than by guzzling glucose. In one study, eight men with high scores on a test of abstract, nonverbal reasoning displayed reduced energy use in areas of the brain uniquely activated by the test (SN: 2/27/88, p.137).

A second PET investigation documented sharp drops in overall brain activity for another eight men after 1 to 2 months of daily practice playing Tetris, a computer game that required them to rotate and move variously shaped floating blocks to create solid rows of blocks (SN: 4/4/92, p.215). Those scoring highest on a test of abstract reasoning ability showed the least brain activity while playing Tetris.

Many researchers nonetheless assume that a physiological Protestant ethic animates intelligence — that is, the brain must work harder to reap a smarter harvest. Yet brain efficiency continues to infuse intelligence in Haier's studies. He now reports that the brains of 17 mildly retarded people toil substantially harder than those of 11 people with above average intelligence.

Mildly retarded volunteers, including seven with Down's syndrome, scored between 50 and 70 on a standard IQ test; the other participants had IQ scores of 115 or greater. IQ scores most commonly fall between 90 and 110.

Researchers gave both groups PET scans as the volunteers performed a simple attention task that required them to scan numbers on a computer screen and press a button whenever a zero appeared.

The retarded group showed about 20 percent greater energy use throughout their brains than did the comparison group, Haier asserts. No evidence of brain damage emerged in the retarded individuals.

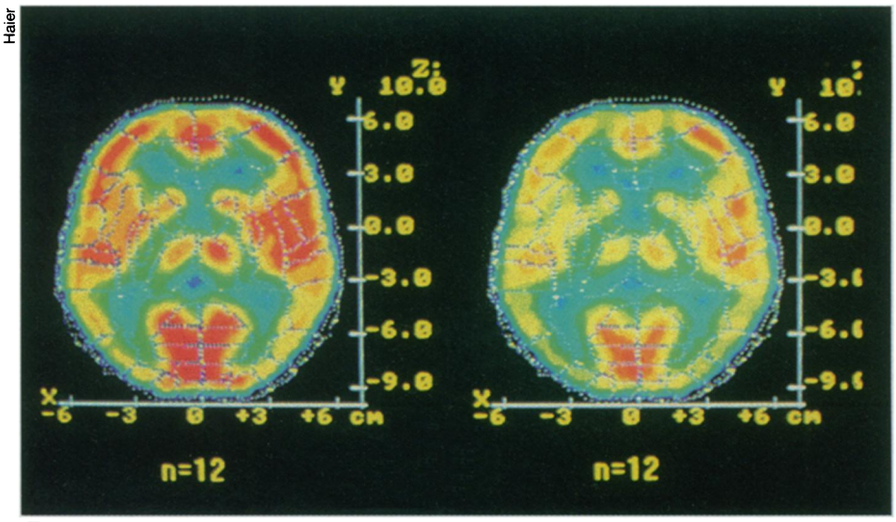
Causes of mental retardation often prove difficult to discern, but Haier theorizes that some cases may involve an overload of cell connections, or synapses, in the brain. Other scientists have found that brain development typically involves a massive flourishing of synapses until around age 5, followed by a gradual pruning of the synaptic thicket until about age 20.

"This process may allow the brain to become more efficient at thinking," Haier holds. "But it may not occur for some retarded people."

Glucose efficiency provides only a partial picture of the intelligent brain, however. Another PET study directed by Haier uncovered a substantial jump in brain activity for 14 high-IQ men who tackled a difficult version of a memory task after having completed an easy version of the same task. In contrast, brain activity dropped slightly for 14 average-IQ men who moved from an easy to a difficult version of the same memory task.

Participants studied strings of digits on a computer screen. They then repeated them backwards from memory. Hard and easy versions — containing more and fewer digits, respectively — were

Haier



PET images show glucose use averaged across the brains of 12 volunteers. A higher level of cerebral activity, indicated by red areas, occurred during a five-item memory task (left), compared to a three-item memory task (right).

established for each volunteer, based on his performance on memory tests that preceded the PET trials.

High-IQ men may marshal more brain fuel on difficult versions of the digit task to support the use of energy-intensive mental strategies for remembering and manipulating numbers, Haier suggests. Brain efficiency may aid only some types of thinking, at least for people of high intelligence, he adds.

In a related PET investigation — perhaps his most intriguing to date — Haier finds that a harder-working brain, not a more efficient brain, appears to facilitate superior mathematical ability in males, whereas the reverse holds for females.

Haier's group obtained brain scans from 44 male and female college students during a mathematics reasoning test. Half of these students — 11 men and 11 women — had scored above 700 (out of a possible 800) on the math portion of the Scholastic Aptitude Test (SAT). The rest had average scores on the same test, none of them exceeding 540.

High-SAT men displayed large increases in energy use throughout their brains; brain activity rose to a lesser extent in men with average SAT scores. In contrast, high-SAT women displayed marked drops in cerebral exertion, except for a small island of heightened activity in the caudate nucleus. A smaller dip in glucose use and less caudate nucleus agitation characterized average-SAT women.

The caudate nucleus produces the chemical messenger dopamine, which has not previously been associated with mathematical ability. If elevated dopamine secretion indeed invigorates women's math capacities, their performance on math tests should suffer after receiving a dopamine-blocking drug. Haier hopes to conduct such a test.

He also plans to conduct PET studies, in collaboration with psychologist Camilla Benbow of Iowa State University in Ames, of mathematically precocious children who scored above 700 on the SAT math test before the age of 13.

"For now, it looks like brain capacity is more important for high math ability in males, and brain efficiency is more important for high math ability in females," Haier contends.

Julian C. Stanley, a psychologist at Johns Hopkins University in Baltimore, suspects that Haier may be right. In ongoing national studies of 12-year-olds, he finds that boys outnumber girls at the highest levels of math achievement by about 3 to 1. Math scores rise sharply in girls who cite strong "aesthetic" values, such as a sensitivity to form and beauty, Stanley asserts; "theoretical" values, such as an emphasis on finding out how machines work, show the strongest link to high math scores in boys.

"I wouldn't be surprised if further brain studies show a different cerebral organization for males and females, with some overlap, on mathematical intelligence," Stanley maintains.

Future PET studies can also tackle the controversial status of general intelligence, Haier adds. If a variety of intelligence tests activate a core group of brain areas, arguments for the existence of a general intelligence grow stronger; if different tests produce distinct patterns of energy use in the brain, the data tilt toward theories of more than one type of intelligence.

In the meantime, more than one type of brain scanner shows promise as a tool for studying intelligence. An ongoing project at Case Western Reserve University in Cleveland, directed by psychologist Douglas Detterman, employs functional magnetic resonance imaging (MRI) to track brain activity during two mental tasks. Functional MRI produces a magnetic field that measures changes in cerebral blood flow and yields a more precise map of brain activity than PET does.

"It's hard to explain the meaning of Haier's findings at this point," Detterman remarks. "This shows how ignorant we still are about the relation between behavior and the brain." □