Half a career spent trying to find the right questions to ask about the nature of human intelligence

In search of the zipperump-a-zoo

ROBERT J. STERNBERG *delivered the Broadbent Lecture at the Society's London Conference in December 1999.*

PROFESSOR Wormbog had every beastie in his collection except one (Mayer, 1976). He had everything from A to Y: an askingforit, a blowfat-glowfish, a croonie, a diddly-dee, an errg, a fydolagump, and everything else up to the yalapappus. But he lacked the crucial Z: the zipperump-a-zoo.

He therefore set out to find the missing zipperump-a-zoo, and looked everywhere, including the most exotic places in the world. But the zipperump-a-zoo eluded him. Finally he gave up, came back home, and went to sleep, exhausted. As soon as he fell asleep, a whole tribe of zipperump-a-zoos emerged to party, right in his house. They had been there all the time, hiding.

In asking in what exotic place they might be, he had neglected to ask whether they might be in the most obvious place of all, right in his own home. Because he had asked the wrong question, he emerged with the wrong answer.

Having just turned 50 years of age, and having finished what I optimistically hope will be the first half of a career (ages 25–50), I hope I can be permitted the egocentric self-indulgence of recounting the tale of a search for my own zipperump-a-zoo — the nature of human intelligence.

I have learned a crucial lesson from Professor Wormbog: you will never come up with the right answer if you ask the wrong question. I still have not figured out quite the right question, but that's fortunate, because there is still, I hope, that second half of my career.

It is sometimes said that as professors age their writings and lectures contain less and less data and more and more stories, until finally there are only stories. As I hope I am only half way through my career, perhaps what I say here will be what for me would be an optimal half-and-half split.

But whatever the proportions, I hope now, as ever, that the data are always in the service of the story (Sternberg, 1990). This is because I believe that, in science, data should ultimately be in the service of theory. At the same time, theory needs to be enriched with data to prevent the theory from telling a vacuous just-so story.

My own field of human intelligence has seen too many instances both of data without meaningful theories and of bloated theories without meaningful data. I hope to contribute to neither of those two unfortunate traditions.

In recounting this tale, I tell it from my own point of view, but I wish to emphasise that I have done nothing by myself. Without support from my parents, some of my teachers, research advisers, granting agencies, and most importantly, my research group at Yale, there would be no story to tell. The critical lesson of the story is that what seems to be a complete answer at one stage of a career seems, at a later stage, to be a woefully incomplete answer.

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Prehistory

The prehistory of my search began when I was a primary-school student and turned in a dismal performance on the required group IQ tests. I was so test-anxious I could hardly get myself to answer the questions. When I heard other students turn the test pages, it was all over for me.

For three years, my teachers thought me stupid, and I obliged, pleasing them by realising their self-fulfilling prophecies for me. They were happy, I was happy, so everyone was pretty damn happy.

In grade 4, at age nine, I had a teacher who believed in me, and to please her, I became an 'A' student. I also learned how, when authority figures set high expectations for their students, it is amazing how quickly those students can defy earlier low expectations.

By age 13, I was determined to understand why I was now achieving at high levels despite my low IQ, so I did a science project on mental testing. I found the Stanford-Binet Intelligence test in the adult section of my town library, and thought it would be good practice to give it to classmates.

I chose poorly. The first person I selected was a girl in whom I was romantically interested, and I soon discovered that giving a potential girlfriend an IQ test is a bad way to break the ice.

The second person I chose tattled on me, and I ended up in serious trouble with the school authorities when they learned I was giving IQ tests to my classmates. After they threatened to burn the book if I ever brought it into school again, I went underground, only to re-emerge some years later.

I also thought it would be a good idea to create a group test that had not just eight or nine subtests, but two dozen. My idea was to improve IQ testing by giving a wider range of subtests. I had asked the wrong question — whether adding more of essentially the same kinds of subtests to create a super-duper-extra-long test would substantially improve reliability or validity. The answer was no.

I quickly stumbled into the general intelligence factor (*g*), which represents the individual-differences variation common to virtually all conventional psychometric tests of intellectual abilities. I was a bit too late, having rediscovered what Charles Spearman (1904) had already discovered at the start of the 20th century and many have rediscovered since.

Spearman believed the *g* factor to represent 'mental energy'. Other psychologists have had other ideas about what it might represent, but the question remains unresolved even today.

At age 20, as a junior in college, I thought I really had the solution. The answer was not more tests, but more refined scoring of the items already in tests. So I devised partial systems of scoring of psychometric test items (can yield zero, partial, or full credit). But I discovered, as had many of my colleagues at the Educational Testing Service (where I worked for the summer), that partial scoring adds very little reliable or valid variation in test scores.

Wrong question again. The answer was not to be found in cosmetic manipulations such as adding more of essentially the same kinds of items or in seeking to extract partial information from such items. And so ended my largely futile prehistory as an apprentice.

Modern history

Sta ge 1: Componential analyses of anal ytical abilities

As a first-year graduate student I despaired of having any good ideas for studying intelligence. One day, I saw Betty, my then wife, using 'People Pieces' in her work — a maths-manipulative material for young children consisting of small square tiles bearing images that vary with respect to four binary features — colour, height, weight and sex. I visualised creating analogies from them, and so began my efforts at what I came to call componential analyses of human abilities.

The basic idea of componential analysis is that, underlying intelligence is a series of information-processing components. The questions intelligence researchers should be asking are not merely what psychometric factors underlie their tests, but also (a) what information-processing components underlie the tests, (b) on what forms of mental representation these components act, (c) how the components combine into coherent strategies for solving the problems, (d) how long each component consumes in real time, and (e) how liable each component is to errors in implementation.

I started by describing componential analysis in detail and showing its implementation with various kinds of analogies, such as 'People Piece' and verbal and figural ones (Sternberg, 1977).

For example, in the analogy 'hot is to cold as black is to (a) white or (b) dark', individuals would use several information-processing components. They would *encode* the first and second terms of the problem, figuring out what each word means. Then they would *infer* the relation between 'hot' and 'cold'; namely, that the relation is one of opposites. Then they would *encode* the third term of the problem.

Then they would *map* the relation of opposites on to the second half of the problem. They would *encode* the last two terms of the problem, and *apply* the relation of opposites. Next they would *compare* the two answer options, and *respond* with the better option — 'white'.

I later extended these analyses to many other kinds of test items (Sternberg, 1983). These included:

- *inductive-reasoning problems*, such as classification problems (e.g. 'Which word does not belong with the others? (a) automobile, (b) car, (c) boat, (d) wheel') and series problems (e.g. 'Which word comes next in the following series? infant, child, adolescent, (a) adult, (b) fetus');
- *deductive-reasoning problems*, such as linear syllogisms (e.g. 'Tom is taller than Dick; Dick is taller than Harry. Who is tallest?'), categorical syllogisms (e.g. 'All skegans are klabers; all klabers are dabins. Are all skegans then dabins?'), and conditional syllogisms (e.g. 'If you are a skegan, then you are a klaber; Tom is a skegan. Is Tom therefore a klaber?'); and
- *verbal-comprehension problems*, such as acquiring meanings of words from context (e.g. 'The blen arose on the horizon. What does blen mean? (a) sun, (b) lake'), and choosing synonyms or antonyms (e.g. 'What is the opposite of black? (a) white, (b) dark').

Componential analyses could serve many useful purposes. They could tell psychologists how people were processing IQ-test-like problems in real time. The models accounted for large proportions of both stimulus and person variation in reaction-time data.

Interesting specific findings also emerged. For example, I found that being smart is not just a matter of being fast: better reasoners tend to spend relatively more time encoding the terms of analogy problems, but relatively less time operating on those encodings (Sternberg & Rifkin, 1979). They want to make sure they understand what they are doing before they go ahead and do it.

The methodology also enabled me to discover why people may be doing poorly on a given type of test item. For instance, is a low verbal-analogies score due to problems understanding the vocabulary required to solve the analogies or is it due to faulty reasoning operating on known vocabulary (Sternberg, 1977)?

Stage 1 of my research was actually divided into two substages. In Substage 1a, I merely posited the existence of information-processing components (Sternberg, 1977).

In Substage 1b, I distinguished metacomponents — higher order executive processes that decide what to do, how to do it, and how well it was done; performance components — lower order processes that execute the instructions of the metacomponents; and knowledge-acquisition components, which figure out how to do things in the first place (Sternberg, 1980).

Using this framework, I was able to discover that better reasoners tend, for example, to spend relatively more time on the metacomponent of global planning, but less time on the metacomponent of local planning, than do poorer reasoners (Sternberg, 1981). In other words, the better reasoners realise that they need to plan in advance so as to conserve time and effort when they later begin getting into the details of the problem.

We were also able to isolate the knowledge-acquisition components used in acquiring vocabulary from context (Sternberg & Powell, 1983), such as selective encoding of relevant cues in distinction from irrelevant cues for figuring out a word's meaning.

But the wrong questions had once again led to the wrong answers, or, to be more precise, incomplete answers. Puzzles were emerging. Why was the regression constant in equations for the mathematical models we were constructing the best predictor of scores on psychometric tests? Were we just rediscovering *g* again, but this time as an information-processing construct?

Why, when we assessed people's implicit (folk) theories of intelligence, were analytical abilities only a small aspect of what people broadly consider intelligence to be (e.g. Okagaki & Sternberg, 1993; Sternberg, 1985a)?

The main factor leading to my puzzlement, however, was really not a research finding, but an observation.

Stage 2: Triarchic theory of human intelligence

I have always been one to get most of my ideas not from reading academic materials or listening to academic lectures, but from my daily experience. And my experience was not fitting my theory. I was teaching three graduate students who provided a curious contrast.

One, whom I have come to call Alice, was brilliant academically and at the kinds of memory and analytical skills conventional psychometric tests of intelligence emphasise. She started off our graduate programme in psychology as one of the top students, but ended up as one of the bottom students. The reason was transparent: Alice was brilliant analytically, but showed only the most minimal creative skills.

I was not convinced that Alice was born creatively retarded. Rather, it seemed more likely that Alice had been so over-reinforced for her school smarts during her life that she just had never had any incentive to develop or even to find whatever creative skills may have been latent in her.

Another student, Barbara, was marvellously creative, if we were to believe her portfolio of research work and the recommendations of her undergraduate professors; but her scores on the largely analytical Graduate Record Examination (GRE) were weak. Other professors were reluctant to admit her because of these GRE scores, and Barbara was rejected from our programme, with mine the only vote in her favour.

I hired her as a research associate, which gave her a chance to show her creative brilliance. Barbara was admitted as the top pick to our graduate programme a couple of years later.

Some years after that, we did a study on 12 years of graduate students in psychology at Yale. The study showed that, although the GRE was a good predictor of first-year grades, it was a satisfactory predictor of little else, such as students' analytical, creative, practical, research or teaching abilities, or of the quality of their dissertation (Sternberg & Williams, 1997).

The third student, Celia, was admitted not because she was spectacular, but because she appeared to be good in both analytical and creative skills. Every programme needs students who are good in several things, if not great in any of them. But Celia surprised us when she was besieged with job offers. She was the kind of person who could go into a job interview, figure out what her potential employers wanted to hear, and then give it to them.

In contrast, Paul, a student who was analytically and creatively brilliant, received many job interviews but only one very weak job offer. In some respects the opposite of Celia, he managed to insult his interviewers at every turn. He was as low as Celia was high in practical intelligence.

I now realised that once again I had been asking the wrong question. By asking what information-processing components underlie performance on conventional mental tests, I had been able to identify how people solve such conventional problems. But I had assumed that these tests measured the universe of skills relevant to intelligence, and my assumption was false. Once again, by asking the wrong question, I ended up with an incomplete answer.

These observations led to the development of the triarchic theory of human intelligence (Sternberg, 1984, 1985b, 1988). This theory has three subtheories. A *componential subtheory* specifies the information-processing components of human intelligence, such as recognising, defining and representing problems.

An *experiential subtheory* specifies the two regions of experience at which these components are most relevant to demonstrating and assessing intelligence. These regions are relative novelty and automatisation.

The former region refers to the solving of problems that are rather different in kind from what one is used to, but not wholly different. A problem that is too novel (e.g. calculus problems for five-year-olds) does not provide a good measure of intelligence. The second region refers to rendering unconscious and automatic a process that starts off as conscious and controlled, such as reading.

A *contextual subtheory* specifies the real-world contextual functions of intelligence: adapting to existing environments; shaping existing environments into new and hopefully better ones; and selecting different environments (usually when adaptation and shaping fail).

Analytical abilities are engaged when information-processing components are applied to relatively familiar problems that are largely academic because they are abstracted from the substance of everyday life. Creative abilities are engaged when the components are applied to relatively novel problems. Finally, practical abilities are engaged when the components are applied to adaptation to, shaping of, and selection of everyday environments.

My group expanded its research into the creative and practical domains, with some interesting results, we thought.

In Stage 2a, we focused on creative abilities, which seemed complementary to analytical ones. Some of this research used convergent measures. For example, we might introduce participants to relatively novel concepts, such as Goodman's (1955) concepts of 'grue' — a colour that is green until the year 2000, and blue thereafter; and 'bleen' — a colour that is blue until the year 2000, and green thereafter.

We pointed out that one could not say whether an emerald was green or grue, because one would not know until the year 2000 (which then seemed rather distant).

Or we might introduce participants to the planet Kyron, where there are four kinds of people — 'plins', who are born young and die young; 'kwefs', who are born old and die old; 'balts', who are born young and die old; and 'prosses', who are born old and die young.

Participants had to solve problems that involved reasoning with these novel concepts. We found that the information-processing component that distinguished the more from the less creative reasoners was the one that measured the ability to transit between conventional (green-blue) and unconventional (grue-bleen) thinking. The more creative individuals found it easier to switch back and forth (Sternberg, 1982; Tetewsky & Sternberg, 1986).

Other studies used divergent measures. For example, we formulated an investment theory of creativity, according to which more creative thinkers are those who buy low and sell high in the world of ideas (Sternberg & Lubart, 1995). In other words, they are people who generate ideas that are relatively unpopular (buy low); convince others of the worth of these ideas; and then move on to the next unpopular idea (sell high).

We had people write stories with diverse titles, such as *The Octopus's Sneakers*; or do art works for topics, such as 'earth from an insect's point of view'; or produce advertisements for boring products, such as a new brand of bow tie; or solve quasi-scientific problems, such as how we could tell whether there are extraterrestrial aliens among us seeking to escape detection. Products were evaluated for their novelty and quality.

Two major findings emerged. First, creativity tends to be fairly but not completely domain specific. Second, it tends to be rather but not totally distinct from psychometrically measured intelligence.

Today, I believe the investment theory was a bit of an oversimplification. The theory holds that creative ideas tend to be unappreciated and devalued. I now believe, however, according to a new propulsion theory of creative contributions (Sternberg, 1999a), that whether creative ideas are valued or not depends on which of seven kinds of creative ideas they are.

Ideas that are consistent with ongoing paradigms tend to be welcome. Forward incrementations, for instance, which move existing paradigms forward, tend to be valued. Redirections, which move existing paradigms in new directions, or reinitiations, which reject current paradigms and start at a different point of departure, tend not to be recognised as creative because they are often too novel for people to appreciate their value. Of course, novelty is no guarantee of quality.

In Stage 2b, which largely overlapped with Stage 2a, we focused on practical abilities. The basic idea motivating this research is that practical intelligence derives largely from acquiring and using tacit knowledge — the procedural knowledge one needs to have to succeed in an environment that is not explicitly taught and often not even verbalised.

For an academic psychologist, for example, tacit knowledge would include knowing how to win acceptance of articles submitted to journals and knowing how to get resources from the Chair of one's department.

We represent this knowledge in the form of production systems, which are ordered series of conditional ('if–then') statements. Thus, one keeps asking which piece of tacit knowledge to apply (the 'if' antecedent) and executes that knowledge (the 'then' consequent) when the right piece of tacit knowledge is found.

We have developed (Sternberg *et al*., 1995; Wagner & Sternberg, 1985) and continue to develop (Sternberg *et al*., 2000) instruments to assess the acquisition and utilisation of tacit knowledge. We have now tested thousands of people in more than two dozen occupations, including academic psychologists.

The tests are all based on the same notion. Participants are presented with scenarios from the everyday life of people going about their business (as students, as employees, or whatever). The participants then either state a solution to the problem posed in the scenario (in one format), or evaluate the quality of alternative solutions proposed to them (in another format).

The results have been fairly consistent across studies. Tacit knowledge typically does not correlate with IQ-based measures, but predicts school and job performance as well as or better than such measures.

The correlations are not always zero. At the lower (but not higher) ranks of military officers, we obtained weak but significant positive correlations.

Among children in rural Kenya, we obtained significant negative correlations. The anthropological members of our team — Wenzel Geissler and Ruth Prince — recognised a fundamental fact about the families' values. The children saw that their path to success was not through obtaining high grades in formal schooling, but rather through acquiring the tacit knowledge that led to adaptation to the demands of village life.

In other words, our measures supplement although obviously do not replace the IQ-based measures. They are not replacements because we are focusing here on practical abilities, whereas IQ-based measures focus on analytical abilities.

But I eventually came to the conclusion that I was once again asking the wrong question. I was emphasising analytical, creative and practical abilities, and thinking loosely in terms of some additive combination rule. Observations of effective people in a variety of occupations convinced me that there was no single combination rule, however.

For example, my two mentors and greatest role models — Endel Tulving and Gordon Bower — are both wonderfully successful psychologists, but have got to where they are in very different ways. There seems to be an infinite number of combination rules.

Stage 3: Theory of successful intelligence

The theory of successful intelligence (Sternberg, 1997, 1999b) is in many respects an expansion of the triarchic theory. It states that people are successfully intelligent to the extent that they have the abilities needed to succeed in life, according to their own definition of success within their sociocultural context.

They succeed by adapting to, shaping, and selecting environments.They do this by recognising and then capitalising on their strengths, and by recognising and then compensating for or correcting their weaknesses.

Thus, there is no one path to success in life, nor even several. Each person must chart his or her own; and the job of the teacher is to help students chart their own paths. Teaching in just one way can never work.

Many societies, especially developed ones, tend to focus a spotlight on just one group of students — those with high levels of memory and analytical abilities. But in doing so, they create self-fulfilling prophecies, developing assessments of ability, methods of instruction, and assessments of achievement that identify as intelligent this one group of students.

Really, societies can create whatever kinds of self-fulfilling prophecies they wish. If they bestow benefits primarily or exclusively on children of certain religions, castes or skin colours, or with certain accents of speech, they can quickly find that only those children succeed. They then convince themselves, as did Herrnstein and Murray (1994), that the success of these individuals represents an 'invisible hand of nature' rather than a system created by the society.

Our research has shown that analytical, creative and practical abilities are largely independent. When students' abilities and

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achievements are assessed for not just memory and analytical abilities, but also for creative and practical abilities, students formerly considered as not very bright can succeed in school at higher levels (Sternberg *et al*., 1999).

Moreover, students taught for successful intelligence do better across grade levels and subject matter areas, regardless of how their performance is assessed, and even if it is assessed merely for memory learning (Sternberg *et al*., 1998). The students learn better because they can use their abilities more effectively, and because the greater interest of the material better motivates them to learn.

Stage 4: Balance theory of wisdom

My very latest work is taking a somewhat different direction. I have come to realise that some of the world's cruellest despots and greediest business tycoons are successfully intelligent. They have played within the sociocultural rules, which they have largely set. Thus, they have been enormously successful, often at the expense of countless others who are left to their own devices, and often to death.

It is for this reason that I have now turned my attention to wisdom (Sternberg, 1998). In my balance theory, I view wisdom as the value-laden application of tacit knowledge not only for one's own benefit (as can be the case with successful intelligence), but also for the benefit of others and institutions to attain a common good. The wise person realises that what matters is not just knowledge, or the intellectual skills one applies to this knowledge, but how the knowledge is used.

This article is based on a lecture dedicated to Professor Donald Broadbent. I knew him only slightly. I of course know that he was one of the foremost academic psychologists of his generation. But what most impressed me about him in my slight acquaintance was not his research on perceptual filters, problem solving, or really, on anything else. What impressed me most was his wisdom.

IQs have been rising over the past several generations (Flynn, 1987; Neisser, 1998). The perpetration of ever worse massacres and genocides suggests that wisdom has not been rising concomitantly.

If there is anything the world needs, it is wisdom. Without it, I exaggerate not at all in saying that very soon, there may be no world, or at least none with humans populating it. Perhaps the only ones left will be zipperump-a-zoos.

For me, wisdom is the true legacy of Donald Broadbent. It is also the further legacy I hope to leave by asking ever better questions for whatever time remains in my professional career.

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