Creative Intelligences

Edited by

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for Section X of The British Association for the Advancement of Science

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Introduction

Professor Richard L. Gregory

Each year, the venerable, though in spirit youthful, British Association for the Advancement of Science meets in a different University City of the Kingdom of the British Isles. The venue for 1986 was Bristol. Bristol was at its peak in the eighteenth century: when its port was the second largest in the Kingdom, and it was the centre for the merchants of tobacco, wine (especially sherry) and, in its recent history, of dubious dealing in slaves. In fact, it must be confessed, its fortunes are largely based upon the selling of sin. As is so often the case, however, this produced some excellent architecture and a general spirit of well-being.

The British Association draws together about 3,000 people each year—youngsters, teachers and scientists—from all over the country, and indeed from abroad to talk, to meet each other, and in present circumstances to deplore the inadequate funding of their lives' work —which, at least as they see it, is aimed at making the present supportable and a viable basis for the future through inculcating learning, teaching, and research. It is indeed difficult to imagine more worthy activity. But then if Bristol's past (of which it is of course, seriously, justly proud) is anything to go by, sin seems to do better than intelligence.

The BAAS is organized into several sections, each with its own special Letter (such as 'J' for psychology) and each—under its general President—with its own Officers, who wear bejewelled medallions. The sections are organised by the Recorders (who have a medallion, for public recognition) and the Secretary (who does not). The Recorder was one of the editors: Pauline Marstrand. The Secretary was Dr. John Durant.

Apart from the serious side of a concentration of lectures and discussions on all manner of scientific issues and social implications, with the occasional excitement of a new discovery, the Annual Meeting traditionally has several highly enjoyable social events. These include a city reception, in which we were honoured by the

Lord Mayor. Each section has its dinner. Our's (Section 'X') was shared with Section 'J's, and was held in the delightful mansion, Goldney Hall, owned by the University. The Dinner, organised by Dr. John Harris and John Barrett—which was in the Orangery, surrounded by gardens including a formal lake, a magic grotto and a folly tower—was gilded by the generosity of the publisher Mr. Adam Gelbtuch (who owns the journal *Perception*) and by the generous contribution of the Institute for Scientific Information. These generosities greatly enhanced the culinary and also the libidinous (in the sense of 'libation' rather than 'libido') quality of the occasion, while placing it within the restricted pocket of the 'X' and 'J' academics and students. Normally science aims at truth through observation; but this party was graced with the remarkable conjuring abilities of Simon Watkins who succeeded in separating appearance from reality with dramatic effect.

The chapters in this book represent the papers presented at Section 'X'. Section 'X' is special—it is the 'General' section, which can deal with any topic. The topic is chosen partly by the Section Committee (which puts in a lot of work each year) and by the President for the year. I had the honour of being President for 1986, when the subject was the very general topic: 'Intelligences'. And of course I sported my Medallion, though with a hope that I would not be confronted too much in public by superior intelligences. Whether this happened or not, the entire occasion was intellectually stimulating for all of us and immense fun.

During this week the EXPLORATORY Hands-On Science Centre held an exhibition, in the centre of the city in the docks at Watershed. This was opened by the President of the British Association—who was about to become President of the Royal Society—Sir George Porter, PRS. It is pleasant to be able to report that, following this auspicious start, a few months later the EXPLORATORY opened on a daily basis to the public in the neo-Classical building, the Victoria Rooms, near the University in Clifton. The EXPLORATORY is designed to enhance the human intelligence of both children and adults, by hands-on interactive experience with working demonstrations and experiments. These are called 'Plores' for exploring, and they do indeed attract people of all ages and induce the delight of discovery.

The chapters of this book represent life-long cogitations of authorities in the broad field of intelligence. The topics range over the development of intelligence in the evolution of species, and its development in children, to intelligent machines, creativity, and puzzling questions of how far intelligence is based on knowledge and knowledge based on intelligence.

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1 Intelligence based on knowledge — knowledge based on intelligence

*Richard Gregory**

There is a paradox in how we think of intelligence. We say that someone who does well by using special knowledge must be intelligent; but we also say that intelligence is demonstrated by succeeding without special knowledge. Thus, we assign intelligence both for lack and for presence of knowledge.

What, then, is intelligence? In normal English the word 'intelligence' has two meanings. Its earlier, and now less used, meaning is essentially *knowledge*, especially hot news, or gossip, or secrets of war. We find this use in 'military intelligence', which does not mean that the military are particularly bright; but only that they have, or seek, special information. Shakespeare's use of the word, in *Macbeth*, is in this sense: 'Say from whence you owe this strange intelligence?' This is the way the word is used before modern psychology.

The new, technical sense refers to IQ (intelligence quotient) tests, designed especially for comparing abilities of children. Such tests were first designed by the French psychologist Alfred Binet (1857–1911), in collaboration with Théodore Simon. Binet was asked at the beginning of this century by his government to find a way of distinguishing between children who were too lazy to learn and children incapable of learning through lack of ability. The aim was to save educational resources for the children who would benefit. But neither these nor later intelligence tests tell us what intelligence is, or what makes man so special compared with other animals. Perhaps, however, this is not a criticism, for much the same is true of measurements in even the most highly respected physical sciences. Thus, a thermometer is useful though it does not tell us what heat is, or what physically underlies the scale of temperature. On the other hand, temperature measures were necessary for discovering that heat is merely molecular agitation rather than a special substance (Caloric).

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Temperature is measured along a single dimension (though with alternative conventional scales) as there is only one kind of heat—molecular agitation of greater or lesser degree. But it is far from clear that intelligence is at all like this. Is there really only *one* kind of intelligence—so that we can all be measured, and judged and compared, on the same (IQ) scale? We readily accept that the temperature of anything may be measured on a single scale (though different kinds of thermometers are necessary) for the human body, eggs, molten steel and stars; but, as Sir Peter Medawar (1977) has cogently argued it is far from clear that there is a single dimension of intelligence, to justify arranging us on a line from dim to bright.

Binet and Simon set problems which were graded along a single dimension in difficulty. By finding out which could be carried out by 50 per cent of the sample of children, in each age group, they established standardised performance scores for each age. Binet defined intelligence so that each individual child's IQ remains essentially constant as he or she grows up—though of course abilities improve enormously from infancy up to adolescence. In spite of the increase in abilities the average IQ score for children of all ages was set at 100 points; which was done by adjusting performance scores, by handicapping for age, up to the age of sixteen. Thus IQ is defined as mental age × 100/chronological age. It is important to note that abilities of children of different ages are not given directly from IQ scores—as abilities improve with increasing age though the IQ scores remain (on average) unchanged.

So IQ scores are not straightforward measures of ability; for they are 'corrected' for normal expected development of skills with age by the mental age/chronological age quotient. The measured ability/age quotient notion breaks down for adults, as there is no improvement for the kinds of ability that are tested for IQ after adolescence—although we go on getting older, and sometimes wiser! So if one had a measured IQ of 100 points as a child, it would sink to 20 points at the age of fifty, if the quotient procedure were extended into adulthood. If all children developed at the same rate, and in the same way, each child's IQ would of course remain constant; but there are different development rates, and the early tests are not always reliable predictors. There are frequently considerable changes of IQ scores through childhood, so even if one does accept IQ scores at face value, as tests of basic intelligence, there can still be optimism that a poor early score will improve. If a child is branded as having a low intelligence, or is hailed as a genius with an IQ of, say, 140+, his parents and teachers are apt to see him in this light. He is expected to remain dull, or to flower into genius, and these expectations can have marked effects. This is shown in experiments in which children are introduced into schools with made-up exceptionally high IQ scores: this boosts them to do rather better than children with the same scores. This is so also for animals in laboratory learning experiments; if the handlers believe some animals to be special, they tend to become special, which is a major reason for 'double blind' experiments.

In order to measure intelligence, however conceived, it is necessary to test observable abilities or skills. But intelligence is not simply performance or ability. It is supposed to underly abilities, from the simplest problem solving to the works of genius. But unless it is thought of as some kind of special (Caloric-like) substance that we possess, in more or less degree, to understand intelligence we need to know the brain's processes and internal procedures by which we solve problems and invent. This kind of understanding is, however, the aim of cognitive psychologists rather than, at least until recently, designers of IQ tests, who are more concerned with comparing individuals than with understanding what it is to be intelligent. It may, however, be practically impossible to compare intelligences without a theoretical understanding of how intelligence works, which is one reason why computer-based artificial intelligence is important in human terms.

Let us return, though, to the two meanings of 'intelligence': possessing knowledge that is *given*, and ability to *discover* and build knowledge. I suspect that thinking about intelligence has been strangled through not disentangling these what-is-given from what-needs-to-be-discovered senses of intelligence.

If the solution to a problem is already known there is no problem to solve. So, problem-solving ability (which is, essentially, what psychologists take as 'intelligence') must be assessed in the *absence* of sufficient knowledge. And if knowledge is required to solve the problem it is important, to be fair, that all the candidates start with the same relevant knowledge. When special knowledge is required comparisons between individuals' 'intelligence' is extremely difficult. Thus, we should expect the musician and the politician to have different kinds of knowledge and so to do very differently on many tests, even though they are equally 'intelligent'. The question is: if they have different knowledge bases, how can we compare their intelligences? This is a problem for comparing children and a much greater problem for adults, who have very different experiences.

One way of isolating the problem-solving of intelligence is to devise tests which do not require special knowledge; or to devise tests requiring only knowledge almost anyone may be expected to have. Another way is to accept that different knowledge-bases will affect performance—but somehow *handicap* people according to their special knowledge. This means, for example, that a history student would get fewer marks for questions on Rome, or the Middle Ages, than a physics student would earn though he comes up with the same answers. So if asked: 'What date was the Magna Carta?' And also: 'What is the gravitational constant?' they would be marked differently for identical answers. The difficulty here, with this second method, is to know how to apply fair handicaps for special knowledge. The problem over the first method (avoiding special knowledge altogether) is twofold. First, one cannot be sure that special knowledge is not involved; secondly, tasks not requiring special knowledge may seem trivial, even insulting, and so may not be performed well. It may, indeed, be that deploying one's knowledge is the most important feature of intelligence. To test people apart from what they have taken the trouble to learn and what they feel secure in may be to miss just what the tester should be looking for: ability do make effective use of knowledge. Some recent intelligence tests do stress the importance of drawing effective analogies, which must come from available knowledge. These tests may be on better lines and better reflect the knowledge-based nature of intelligence.

The problem of how much knowledge is involved in solving intelligence-test problems is especially important for claims that different races or the sexes have, on average, different intelligences. It is quite obvious that people with different racial backgrounds tend to have different experiences, and the same applies to the sexes. So how can races, or the sexes, be fairly compared? One approach is to try to devise tests free of special knowledge; but for comparisons between races this is extremely difficult, perhaps strictly impossible. To take an extreme example; for people with some cultural backgrounds, even the situation of being tested, of having to sit down and concentrate on working out problems and answering questions, is outside their experience. If the second strategy is adopted—to apply 'handicaps'—it is hardly possible to handicap fairly, because it is virtually impossible to assess the effects of cultural differences apart from performance at skills—which makes the situation logically circular.

Let us grasp the nettle and consider, in these terms, claims that men are more intelligent than women. Or, if you prefer, that women are more intelligent than men. In either case, a score suggesting one of these possibilities might be due to the testers having chosen questions or test tasks which are more familiar to the one sex than the other. The greater familiarity, or knowledge, will produce a higher score—but will this indicate greater intelligence? It could signify a lower intelligence. To justify this we would have to know the contribution made by the knowledge, which it is extremely difficult to do. And if there is a genetic component here, it may lie outside what is taken as intelligence. For example, it might lie in physical strength (for tasks such as changing wheels on cars) which makes the task easier, so it requires less intelligence. Even if the test does not involve physical strength, which is clearly sex-related, it may involve experience which has been more easily gained by physically stronger people. Similarly, one can think of converse examples favouring women, for example by their greater dexterity.

However all this may be, there is no doubt that if one asked a sample of men and women the following questions, men would generally do better than women in our society: what does the differential gear in a car do? What is a tee? What does a halyard have to do with blocks and cleats? What is the difference between stocks and shares? But a better score for these questions would be no particular indication of greater intelligence in the sense of more powerful problem-solving ability. For it happens that men in our culture tend to be more interested than women in golf, sailing and investments, as well as in mechanical principles—though of course there are plenty of exceptions. Similarly, if men and women were asked 'What a roux is, what fennel is used for, or what a pommel is', then women might be expected to do better. This means that a test which included a lot of the first items would favour men, while the kinds of items of the second test would favour women. So the result will largely depend on whether the tests are men-favouring or women-favouring. There are physiological differences between the sexes which make some tasks slightly easier for men or for women.

If tests come out with the answer that men and women have *equal* intelligence, this could be due to a successful balancing act by the test designers—to give equal men-favouring and women-favouring test questions. Then the claim that men and women have equal intelligence means merely that the test designers have got their balancing act right to bring about this result. If, on the other hand, they claim that men are more intelligent or that women are more intelligent, this could mean that they have presented too many men-favouring, or too many women-favouring questions—they have got their balancing act wrong. In neither case do we learn about relative intelligences; unless indeed it was shown that measured differences are too great for such an explanation.

This is only the beginning of a complicated situation which has a forest of logical and statistical traps. There is, also, the academic prejudice that academic abilities should be rated highly in the intelligence stakes; so a successful physicist will generally be rated 'higher' than a successful farmer or mechanic. But this may be little more than a reflection of academic arrogance; and of course it is academic psychologists who design intelligence tests.

Can we think more clearly about intelligence? We started by pointing out that the word 'intelligence' has two meanings, the older being given knowledge, and the second, ability to discover or build knowledge. In this second problem-solving, 'psychologists'' sense, knowledge is also important, but in a somewhat paradoxical way. For as we have more knowledge so problems are more easily solved. So, as we possess more of the first sense of intelligence,—we need less of the second sense. Until, with sufficient knowledge, the problem may disappear until we need no problem-solving intelligence. This is a paradox suggesting that it is appropriate to ascribe more intelligence to those who have less knowledge, though we generally associate having a lot of knowledge with high intelligence. This is a muddle that needs sorting out.

The first step, I think, is to recognise that knowledge in any form is always *produced* by some kind of problem-solving. So attaining knowledge requires problem-solving intelligence. Secondly, we may think of knowledge as 'frozen' problem-solving. Knowledge expressed in words, equations—or useful tools or technology—may be selected and 'thawed' for more-or-less immediate use. Thus, once scissors are invented, they solve the problem of cutting paper or cloth. This notion is very like the physical concept of *kinetic energy*, building up *potential energy* which may be used in various ways, such as by pumping water up to a reservoir, for producing electricity for any number of uses. So, using 'knowledge' very broadly, we may suggest the terms *kinetic intelligence* for knowledge production, and *potential intelligence* for the power of knowledge to solve problems. These are the two senses of 'intelligence' that we started with.

On this account, potential intelligence is *available* solutions and answers—which were *created* (perhaps in the distant past) by kinetic intelligence. If our present knowledge is adequate for a current problem or task, then little or no problem-solving—and so little or no kinetic intelligence—is required. Similarly for tools; if we have the right tools a job is much easier than if we have to invent a new tool or process. In this sense tools, as well as books and computer programs, are potential intelligence though they are not in brains. Kinetic intelligence is needed whenever a situation is somewhat novel; for then it is necessary to see how the available tools or symbolically stored knowledge may be applied—which requires an inventive leap or kinetic intelligence.

The issues here are bound up with novelty and creativity. It is absurd to consider intelligence separately from creativity, though test designers have minimised originality as it is so hard to measure. And much as small kinetic energy may release vast potential energy, a small creative step may produce dramatic consequences, for good or ill. So, as potential intelligence builds up over generations the world becomes both more promising and more dangerous. This suggests that although our kinetic intelligence is now less important in many situations, as we have more knowledge than our ancestors, yet it is more important in unfamiliar situations as the range of possibilities, including disasters, is greater.

However this may be, I think we can now see, in these terms, some essential difficulties in the business of measuring intelligence. The major difficulty is that the contribution of stored potential intelligence is overwhelmingly greater than that of the small inventive steps of kinetic intelligence. So the kinetic intelligence that psychologists try to measure is in most situations swamped by the power of knowledge. It is not clear that the kinetic intelligence of problem-solving can be isolated, for measurement, from the immense contribution of the stored knowledge of potential intelligence. We might define intelligence as *the generation of successful novelty*; but this is extremely hard to measure as the novel component of skills is so small.

It is not only living organisms that generate the successful novelty we see as intelligence. Novel solutions are generated most dramatically by the unintentional processes of organic evolution. It is, indeed, striking that the randomness and selection-by-success of evolution has solved inumerable problems (such as photosynthesis) which are beyond individual invention or understanding and remain unsolved by science. Even the simplest living organisms are supreme examples of potential intelligence, as they are solutions to incredibly difficult problems, which were solved over millions of years by the brainless blind steps of natural selection. So although plants are hardly intelligent in the kinetic intelligence sense of the psychologists, they embody immense potential intelligence as created through evolution, though its processes are blind.

And now: what of computers, that are beginning to be intelligent, as they build generalisations and apply analogies from their pasts to solve problems? Will they be blind intelligences, like the organic evolution that is our origin? Or will they, like us, have some understanding, goals, and directed intention to solving problems? If so, will their intentions match ours? Or will intelligent computers lift us out of our biological origins, into a new world of silicon—where our heritage of potential intelligence no longer applies? Then, intelligences that we have created may destroy us by their alien knowledge.

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2 Intelligence and children's development

*Peter Bryant**

There have always been close ties between the devising of ways to measure intelligence and child psychology. The two subjects began at roughly the same time and each at various periods has been directly influenced by advances in the other. These ties are so close and so important that it would be quite hard to understand the twists and turns of the study of intelligence or of children's development without being well versed in both of these topics.

It was like this from the start, which we can put roughly at the first decade of this century. That was when Binet and Simon (1908) devised the first effective intelligence test. Theirs was not the first of these tests: there had been other attempts, most notably Galton's. But Binet and Simon's was the first that really worked and the first, too, to be widely adopted, and one of the main reasons for its success was that it was devised on the basis of data about children.

Binet was a developmental psychologist long before he became an inventor of intelligence tests and he had devised some ingenious ways of showing how striking are the changes in children's ability to remember things and to reason about quantity in general and number in particular. It was he, for example, who first showed how easily children are thrown off course by misleading perceptual cues when they are trying to compare the number of objects in two arrays.

Binet used this early experience of looking at children's development to effect when he began to design his intelligence test. His technique was to include problems in the test only if they were developmentally sensitive—that is to say, only if they turned out to be problems which older children were more likely to get right than were younger children. This simple idea was the key to Binet's success, and it certainly worked. He and Simon assembled an array of problems, from quite easy to very hard ones, and arranged them in such a way that the older children were the greater on the whole was the number

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of problems that they could solve. It soon emerged that the children who could answer more problems than the average child of their age and thus were in advance for their age were also the children who did particularly well at school. In practical terms the test was a success, for it could predict, and still can, in the relatively short term how well children are likely to cope in an academic situation.

Given the immense success of Binet and Simon's test at the practical level it is easy to forget its considerable effect on developmental theory as well. The truth is that it was the beginning of theories about intellectual development. That was because it showed quite clearly that there is such a thing as intellectual development and thus posed a theoretical question which people have been trying to answer ever since.

Here for the first time was tangible, systematic evidence of intellectual development. The whole process of standardising the test had shown that there are systematic changes in what children are able to do and that these changes are strongly related to age. Furthermore the data from the bottom end of some of these developments were genuinely arresting. Binet and Simon showed that there were some surprisingly simple and basic things which were quite out of the range of very young children. Young children could not remember all that many words read out to them by the tester, they could not say what was wrong with simple and absurd statements like 'Fred's feet were so big that he had to put his trousers on over his head', and they seemed unable to solve some pretty simple logical problems: simple inferences and analogies like 'Arm is to elbow as leg is to . . .' were beyond them at first but came to them as they grew older.

It was this last phenomenon—young children's difficulties with simple problems of logic and reasoning which arrested many people's attention, for it raised an interesting possibility. Could it be that the ability to reason and to understand other people's reasoning was something only gradually acquired through childhood?

In fact this sort of question seems to have brought the great developmental psychologist, Jean Piaget, into the subject. He worked for a while with Simon, Binet's old colleague, and Simon suggested that he try out a new verbal test devised by the ingenious Cyril Burt. Burt's test consisted of a set of logical problems which took the form of a particular kind of deductive inference—the transitive inference. If I tell you that Bill is taller than Fred and Fred taller than Joe, you have at your fingertips not only those two pieces of knowledge, but also the information which follows from them—that Bill is taller