Neuroscience

Of mice and mentality

Steve Blinkhorn

Evidence of a general learning ability in mice — that there is a good correlation between an individual's performance in tasks that make different processing demands — suggests a parallel with humans.

Why isn't everyone a genius? Argue it whichever way you like, people manifestly differ in the ease with which they learn, and, whatever the reason, we have to provide for these differences in education, training and employment. But for the study of the elementary processes of learning, psychologists have traditionally looked to laboratory animals: rats, mice and pigeons. The practice of using inbred strains eliminates as far as is possible the influence of individual differences in the subject pool, but has led to the neglect of the study of these differences for their own sake.

Now Louis D. Matzel and collaborators, in what in the future may be seen as a seminal study, have reported the tentative identification of a general learning ability, varying from one individual to another, in mice (*J. Neurosci.* **23,** 6423–6433; 2003). Their work invites independent replication, not least for its 'crossover' character: it remains a rarity for research to combine the skills of the laboratory experimental psychologist with the correlational methods that dominate the study of individual differences.

There are two major elements in the design of the study that should be noted. First of all, Matzel *et al.* used animals from an outbred strain of laboratory mice, on the basis that they show greater behavioural variability — the very opposite of the usual requirement for minimum inter-individual variation (although we have no indication of how laboratory strains might differ from wild populations). Second, five tasks were chosen that differ greatly in their sensory, motor, motivational and information-processing demands, and in which the possibility of transfer of learning from one task to another is minimal.

For instance, the passive avoidance of sensory overload and the active running of a Lashley maze to gain a food reward require quite different information processing and involve different control modalities (aversive as compared with appetitive), different motor activity, and so forth. The other learning tasks were odour discrimination, fear conditioning and a water maze. The animals showed marked variation from individual to individual in all the tasks. The authors also collected some additional measures, including three aspects of free-field behaviour (such as speed of running), the number of faecal pellets deposited during free-field activity, and body weight.

Of the five tasks, the highest correlation found, 0.47, was between performance in the Lashley maze and on the passive avoidance task. To a physical scientist used to seeing near-exact correspondence, a correlation of 0.47 is a paltry thing. But to a psychologist looking at two such different kinds of task, it is the kind of result that raises the hairs on the back of your neck, and sets the pulse, if not racing, then up to the canter.

In fact, the pattern of correlations for individual mice between all five learning tasks is entirely positive, and although not all of the positive correlations are high, they are sufficient to define a single factor in a factor analysis, which loads the five learning tasks plus the proportion of time spent in the more open areas of the free field. Body weight and number of faecal pellets have no systematic relationships to the other variables, and overall free-field activity and speed of running, although highly correlated with each other, have unsystematic associations with the other variables.

So, have we barked our collective scientific shins against a rodent version of IQ? And do we have here an insight into the nature and origins of human intelligence? The 'ability to learn' is a relatively uncontroversial member of the long list of proposed definitions for intelligence, and Matzel *et al.* have provided some plausible evidence — from impressively controlled experiments — of an influence on learning that cannot be explained by common elements in the tasks. When it comes to the size of the factor, this study yields estimates in the same broad range as has been suggested for the influence of *g*, the general-intelligence factor in humans.

But the sample size, at 56, is a shade uncomfortably low for a factor-analysis study of ten variables: the standard errors of the correlations are of the order of 0.14, so some care is needed in weighing the existence of pattern among the correlations, and in tolerating the fact that some of them are not significantly different from zero, in a conventional bivariate significance test. (The authors kindly made their raw data available to me for independent checks, to ensure that their results are not the outcome of particular choices of factor-analysis methods.)

This is a dilemma for any researcher stepping over the venerable boundary between experimental and correlational approaches to psychology, and Matzel and his collaborators are to be congratulated on striking the right note of caution in reporting their

100 YEARS AGO

A correspondent of the *Times* directs attention to a supposed cure for the mysterious malady known as mountain sickness. The discoverer of the specific is a Russian topographer named Passtoukhof, who, for some years past, has been making ascents in the Caucasus where he has climbed the Grand Ararat, Mount Kasbek, and Mount Elbruz. At such high altitudes as these it is easy to understand that the question of mountain sickness becomes a serious one, and on more than one occasion M. Passtoukhof has found not only himself, but all the other members of his expedition, completely prostrated by it. On one of these occasions it occurred to him to try the experiment of lighting his spirit lamp and making some tea, which he administered to himself and his companions in an almost boiling condition, with a result that far exceeded his expectations. Almost immediately the more serious symptoms disappeared…

From *Nature* 27 August 1903.

50 YEARS AGO

***Christianity in an Age of Science.* The problem of the relation of religion and science is not dead, as we are often told, but has been made obscure because it has become difficult to define the issue clearly… It is one of the many merits of Prof. Coulson's recent book that he is quite clear on what he is talking about… This little book, consisting of three lectures given under the Riddell Memorial foundation, contains more sound sense on the subject than most works five times its size, for it deals with the ultimate issues and keeps to the point. The challenge of the two universes and two systems of knowledge — the scientific and the religious — is always before his mind. He rejects any theory which would vindicate religion by somehow inserting it into the scientific universe, finding a place for it either in the yet unexplored territory or in the incoherences which can be discovered in scientific conclusions. Perhaps he is a little too hard on theologians who find something of interest to them in Heisenberg's uncertainty principle, for if determinism breaks down in one part of Nature, it may well be only an appearance, or a useful fiction, elsewhere; but undoubtedly he is splendidly right when he says, "If God is here at all, it must be at the beginning of science and right through it".**

From *Nature* 29 August 1953.

findings. Spearman's announcement of his discovery of the human general-intelligence factor in 1904 was far less cautious in tone, although from a modern perspective his sampling was less controlled, his sample sizes were of the same order of magnitude, and his experimental controls were, by any standards, rather poor.

A promising pilot study, then? Rather more than that. First of all, we now have five carefully described tasks that can serve to define a reference paradigm, and an example of care in experimental design that should set a benchmark for further work. Second — and this is not immediately obvious from the published paper — there are suggestive patterns buried in the correlation matrix that could be rather productive in determining the next steps, in particular with regard to the relationship between learning and emotionality. And finally, the researchers have performed a signal service in demonstrating how the distinctive skills of what Lee Cronbach once called "the two disciplines of scientific psychology" can combine to open lines of enquiry, and to shed new and refreshing light on the underpinnings of differences in behaviour. ■

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Mechanics

Friction in a spin

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The mechanics of friction may seem the stuff of high-school physics, but only now are some aspects of the problem being understood. A spinning coin is the subject of a new exploration of frictional forces.

One of the most unlikely revivals of our time is that of the science of mechanics. The first great era of classical mechanics culminated in the work of Joseph-Louis Lagrange (1736–1813) and William Hamilton (1788–1856). But in recent decades, work on nonlinear dynamics, chaos theory, fluid dynamics and the mechanics of biomolecules has driven a highly visible revival of this science. The latest instalment, by Farkas *et al.*[1] in *Physical Review Letters*, on the dynamics of spinning disks, illustrates a convergence of the scientific aesthetic and method that is taking mechanics in a new direction.

The reader can easily study the problem addressed by Farkas and colleagues. Take a coin and launch it across your desk, recording the distance travelled. Now spin the coin about the axis perpendicular to its surface as you launch it (Fig. 1) — the coin will travel farther, even if launched with the same initial velocity. Furthermore, the coin will stop moving and stop spinning at exactly the same instant. Why?

The answer lies in the simplest laws of friction. These laws, known as Amontons' laws, state that the frictional force between two bodies in relative motion is proportional to the force between the bodies (in this case, the weight of the coin) and is directed opposite to the relative motion of the bodies[2]. So the non-spinning coin feels a frictional force opposing its motion, and the magnitude of the force is independent of its velocity. This force will eventually bring the coin to a halt.

Consider now the spinning coin. At one edge the spinning motion increases the relative motion of the coin and surface, and at the other edge it decreases the relative motion of the coin and the surface (Fig. 1). If the coin spins fast enough, the edge with decreased relative motion will actually move backwards with respect to the surface, even if the overall motion of the coin is forwards. Thus the frictional force from the surface on this edge actually acts to accelerate the coin, causing it to move farther before stopping.

Although striking, this observation is somewhat trivial. The next conclusion drawn by Farkas *et al.*[1] is far less so. The coupled equations describing how the spinning motion of the coin and its velocity both decrease with time are highly nonlinear. Nevertheless, these authors' delicate mathematical analysis proves that not only does the spinning coin travel farther, but its spinning and its lateral motion stop at the same instant.

Farkas *et al.* also point out another surprising feature of this system. Suppose that we perform the same experiment, not with a coin (whose thickness is much smaller than its diameter) but with a cylinder whose height is comparable to its diameter. The varying frictional forces at the base of the cylinder as it moves will generate a torque (an angular force) about the centre of mass of the cylinder, which will make it bear down more heavily on some parts of its contact footprint, and rest more lightly on other parts. The result is similar to what is known as a Magnus force. Farkas *et al.* show that, as the cylinder moves forwards, its path will tend to curve, much like that of a charged particle in a magnetic field or a fluid (or superfluid) vortex in a steady flow. The direction of path curvature for a charged particle is determined by the sign of its charge, but for the cylinder (as for the vortex) it is determined by the sense of its rotation.

What does all this have to do with the revival of mechanics? No doubt string theorists and creators of Bose–Einstein condensates will be bemused to discover that they are sharing academic departments with colleagues whose idea of fundamental physics involves spinning coins. All give lip service to the notion that exceedingly simple systems can behave in very complex ways, but many are still surprised when faced with a new example of this phenomenon.

Except that a coin sliding on a table is not a simple system. Frictional forces introduce fundamental nonlinearities into the behaviour of mechanical systems, nonlinearities that yield the rich behaviour analysed by Farkas and colleagues. The origin of these nonlinearities lies in a separation of scales. The weight of a coin is not sufficient to distort its shape — a coin is nearly rigid under terrestrial gravity. However, a coin resting on a surface is held up by a relatively small

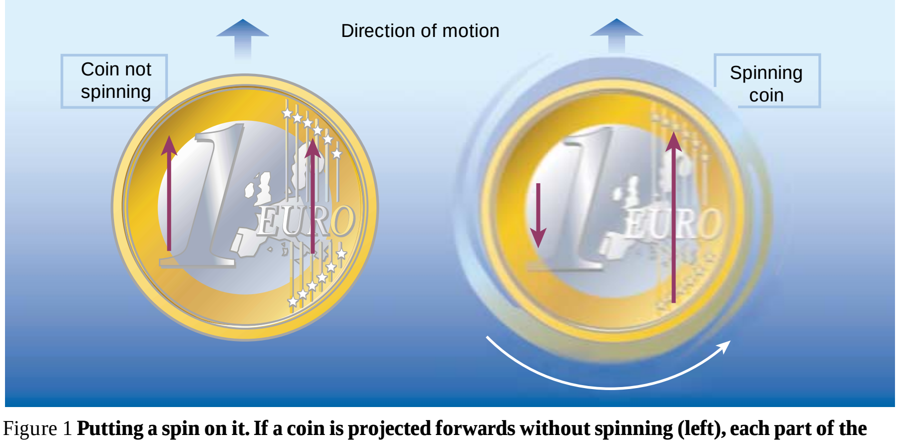

Figure 1 **Putting a spin on it. If a coin is projected forwards without spinning (left), each part of the coin has the same velocity relative to the underlying surface (red arrows). If the coin is set spinning as it is projected (right), different parts of the coin have different relative velocities with respect to the surface: one edge of the coin is actually moving backwards relative to the surface and as a result the coin feels a lower net frictional force.**