molecules inside the cavitand are from outside the liposome.

Further development of cavitand liposomes as drug-delivery vehicles will undoubtedly see the addition of stealth and cell-targeting properties. In fact, Kubitschke *et al.* have already used eight short chains of poly(ethylene glycol) — the water-soluble polymer that forms the repulsive shell of most stealth liposomes — to line the rim of their cavitands so that the molecules retain their binding properties in water (Fig. 1d).

A class of vesicle related to liposomes is the polymersome[15] — vesicles that are made from amphiphilic polymers, rather than lipids. Another possible extension of the authors' work would therefore be the development of polymersomes formed from cavitands that have hydrophilic and hydrophobic polymers attached at opposite ends. Polymersomes are tougher than liposomes, and can sustain greater deformation before rupture. Aside from chemical delivery, cavitand polymersomes would therefore be suitable for applications in which assemblies of judiciously chosen guest molecules undergo large rates of deformation, such as molecular coatings that have controlled friction properties. ■

Cyrus R. Safinya *and* **Kai K. Ewert** *are in the Departments of Materials, Physics, and Molecular, Cellular and Developmental Biology, University of California, Santa Barbara, Santa Barbara, California 93106, USA. They are also affiliated with the Materials Research Laboratory, University of California, Santa Barbara.*
e-mails: safinya@mrl.ucsb.edu; ewert@mrl.ucsb.edu.

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HUMAN BEHAVIOUR

A cooperative instinct

Acting on a gut feeling can sometimes lead to poor decisions. But it will usually support the common good, according to a study showing that human intuition favours cooperative, rather than selfish, behaviour. SEE LETTER P. 427

SIMON GÄCHTER

In a recent bestselling book, psychologist and Nobel laureate Daniel Kahneman presents a wealth of evidence that much of human decision-making is governed by fast and automatic intuitions, rather than by slow, effortful thinking[1]. Intuitions can sometimes lead us astray, such as when it comes to processing statistical information, but our 'gut feelings' also serve us well in many common situations. One interesting question to ask is how intuition influences social decisions that pit self-interest against collective benefit. Does intuition support cooperation, or do people need time to reflect before deciding to pull their weight? On page 427 of this issue, Rand *et al.*[2] present evidence that the intuitive human reaction is to cooperate, whereas reasoning makes people somewhat more selfish.

If evolution favours self-interest, then people should be equipped with intuitions that help them figure out how to maximize their individual gain[3]. However, recent research in the behavioural sciences challenges the idea that people are mostly selfish[4]. Some theories to explain variation in individual behaviour, based on social preferences[5], assume that people differ in their motivation to act in a cooperative manner[6], but not in their reasoning style. Furthermore, psychological studies have suggested that moral judgements are often made intuitively[7], and because many people view 'freeloading' on other people's contributions as morally blameworthy[8], it is plausible that moral intuitions support cooperation.

To investigate directly the role of intuitions in cooperation, Rand and colleagues used a series of ten public-goods game experiments. In these games, people can choose to either keep an allocation of resources for themselves, or contribute all or a portion of their allocation to a collective pool, which is then distributed evenly among all players. The authors conducted some of the games using an international group of subjects sourced from an online labour market (Amazon Mechanical Turk)[9], and others were conducted in person in the laboratory.

Because intuitions are quickly available, whereas deliberation takes time, Rand *et al.* started by investigating the link between response time and contributions. Previous research on response time across a variety of decisions shows that people choose intuitive options more quickly than those requiring cognitive effort[10], and results from a simple sharing experiment suggest that faster choices are more selfish[11]. However, this is not what Rand and colleagues found in their online experiments. Instead, their results indicate that contributions and decision time are negatively correlated — the faster half of the decision-makers contributed, on average, about 67% of their allocated resources, whereas the slower half contributed about 53%. The authors also detected a similar relationship between response time and cooperation in experiments conducted in person, so the observed correlation seems to be robust.

But correlations are of course no proof of causation. To try to plausibly demonstrate a causal link, Rand and colleagues put the game players under time pressure and observed how this affected their decisions. Previous results from bargaining-game experiments suggest that time pressure leads to fairer outcomes[12] and also increases the likelihood that a person will impulsively reject an unfair offer[13,14]. Furthermore, having to decide under time pressure is stressful, and stress also increases pro-social behaviour[15]. So it is clear that time pressure, which favours intuitions over reflection, influences social considerations. Rand *et al.* show that this extends to cooperation: in their experiments, people under time pressure contributed significantly more than those who made their decisions with no time limit or with a forced delay. Thus, it seems that forcing a person to decide more rapidly — by intuition — increases their tendency to cooperate.

In a final set of experiments, the authors used a writing task to prime participants to think intuitively or reflectively before performing the public-goods game. They found that those primed to use intuition contributed more than those put in reflective mode. Rand and colleagues also found that people who consider their interaction partners in daily life to be cooperative cooperate more when primed to use intuition than when primed to use reflection. This result is consistent with a point made by economics Nobel laureate Herbert Simon, who said that "intuition is nothing more and nothing less than recognition"[16]. Thus, it seems that when people are accustomed to cooperative partners, they develop cooperative intuitions.

Rand and colleagues' study raises interesting concepts for experiments in the social sciences, both in terms of questions that would be worthy of further investigation and how to conduct such experiments. For example, their findings suggest that the common practice of asking participants comprehension questions before an experiment will provide conservative estimates of cooperativeness, because the questioning will put people into reflective mode, which Rand and colleagues have shown is likely to result in them behaving less cooperatively. So is this questioning practice justified? It may be in many cases, such as in studies of people's economic decisions, as economists are typically interested in reflected behaviour.

The study also indicates that intuitions may be particularly important in novel situations, and that experience might trigger reflection that either supports or modifies the initial intuitions. Should economic theories based on social motivations[5] take intuitions into account even if the main importance of intuition is (only) in initiating cooperation? Future research may clarify this question. Furthermore, the authors observe that many (but not all) people are cooperative whether deciding quickly or slowly, intuitively or reflectively, and time pressed or not. For example, even in the experiments in which Rand *et al.* recorded the biggest difference between intuitive and reflective contributions, the contributions made under reflective conditions exceeded the difference added by intuition. Economic and evolutionary theories should attempt to explain these findings.

Finally, existing research suggests that some people are selfish free-rider types, whereas others are conditional cooperators who are willing to contribute if others do so[6]. This observation needs to be squared with Rand and colleagues' results: might it be that conditional cooperators are intuitively cooperative and selfish people take a reflected free ride? The authors have demonstrated that, on average, our intuition is to cooperate, but further studies are needed to understand the variation in this behaviour between individuals. ■

Simon Gächter *is in the Centre for Decision Research and Experimental Economics, University of Nottingham, Nottingham NG7 2RD, UK.*
e-mail: simon.gaechter@nottingham.ac.uk

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MATERIALS SCIENCE

The matryoshka effect

By tailoring the architecture of a bulk material at several different length scales, the ability of a semiconductor to convert heat into voltage has been optimized to a groundbreaking level of performance. SEE LETTER P.414

TOM NILGES

The story of thermoelectric materials, which convert heat into electric voltage, began in the early 1950s as part of the scientific plans for the first manned mission to the Moon. An effective, simple and long-lasting energy source was needed to supply the astronauts at their destination. The solution — a thermoelectric generator based on lead telluride — is still working today on the Moon's Mare Tranquillitatis. On page 414 of this issue, Biswas *et al.*[1] describe what is probably the ultimate optimization of the thermoelectric properties of lead telluride, 43 years after that historic Moon landing. They have doubled the efficiency of the material compared with that used in the first generator, a feat that is not only a tremendous step for one group, but also a giant leap for thermoelectrics.

Thermoelectric generators consist of several 'stacks' — devices in which multiple semiconductor blocks are sandwiched between two electrodes. Each stack produces an electric potential difference if there is a stable, long-lasting temperature difference across it. Two types of semiconductor are needed: an n-type semiconductor, in which a material is 'doped' with a small amount of another material to produce an excess of electrons; and a p-type semiconductor, in which doping produces an excess of positively charged voids called holes, which can act as charge carriers.

The semiconductor blocks are arranged so that opposite sides are connected to different electrodes. If a thermoelectric stack is heated on one side, a potential difference is created by the transfer of electrons (or holes) within the device from the hot to the cold end. In this set-up, the device converts thermal energy into electric energy. Alternatively, if a current is supplied to such a device, then the electric energy can be used to generate a temperature difference between the two sides. In other words, the stack acts as a cooling device.

The improvement of existing thermoelectric materials to achieve more effective energy conversion, or the development of new ones, is a demanding task for chemists, materials scientists and engineers. In general, the thermoelectric process within a material and its efficiency are related to three properties: the Seebeck coefficient, which defines the material's ability to generate a potential difference in response to a temperature difference; the electrical conductivity, a measure of the transport

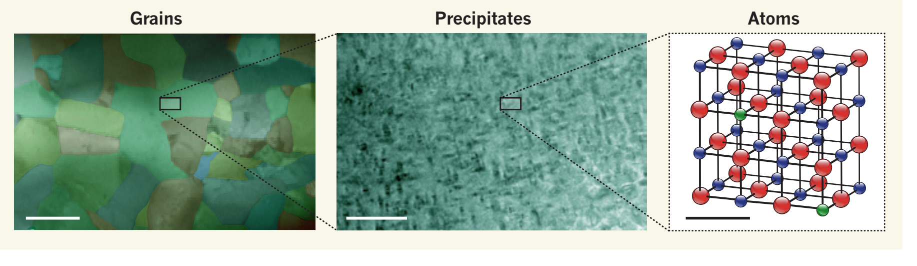

Figure 1 | Better by design. Biswas *et al.*[1] have optimized the thermoelectric properties of lead telluride by controlling its structure at many different length scales. For best performance, the material must contain: grains at the mesoscale (hundreds to thousands of nanometres); nanoscale precipitates of an additive, strontium telluride (several tenths to a few nanometres); and trace amounts of sodium (green atoms), inserted into the material's lattice of lead (blue) and tellurium (red) atoms. The approach works by reducing the thermal conductivity of the material. Scale bars (left to right): 1,000, 50 and 0.5 nanometres.