The Poor's Poor Mental Power

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responding charge appears at the interface with the dielectric elastomer (see the figure). The enormous difference between the capacitance of the double layer and the dielectric leads to a potential across the dielectric that can be millions of times greater than that across the double layer. As a result, potentials in the kilovolt range can be realized in the DEA without electrochemically degrading the hydrogel.

High-frequency actuation is also possible. Careful analysis shows that switching speeds in practical systems are limited only by mechanical inertia. Furthermore, because the stiffness of the hydrogel can be thousands of times smaller than that of the dielectric, actuation can occur freely, without mechanical constraint. These attractive characteristics are complemented by an additional, interesting feature: Hydrogels can have exceptionally high optical clarity across the visible range, thereby opening up a range of application possibilities enabled by transparent actuators.

The authors formed DEAs with this design simply by laminating films of polyacrylamide hydrogels formed with salt water onto the surfaces of dielectric elastomers. Such actuators can change their dimensions by nearly a factor of 2 and switch with millisecond speeds. As a demonstration, the authors built loudspeakers that produce high-fidelity sound throughout the audible range. The thin, planar geometries of these devices, taken together with their nearly complete optical transparency, foreshadow interesting applications such as active noise-canceling windows and display-mounted tactile interfaces. Adaptive optics represents another potential field of use. These and other prospects motivate the development of further refinements in the materials, including schemes to prevent drying of the hydrogels and methods to eliminate ionic build-up, hysteresis, and electrical shorting.

The success of ionic hydrogel conductors in DEAs hints at possibilities for their use in other unusual electrical systems, such as new classes of circuits and sensors that have elastic properties and shapes precisely matched to biological tissues for implants, surgical tools, and diagnostic systems that intimately integrate with the curved, dynamic external or internal surfaces of the body (*6*–*10*). Ionic hydrogels can offer favorable mechanics, and they can be biocompatible. Also, their operation exploits transport of ions, much like the intrinsic mode of electrical function in biological systems. Ionics, therefore, provides a natural type of biotic-abiotic interface.

Although the relatively slow speeds and the physical mass transport associated with ionic conduction preclude the general use of hydrogels as alternatives to metals in electronics, many possibilities can be considered. In fact, seminal experiments in the earliest days of semiconductor device research relied critically on ionic conductors to investigate field modulation of contact potentials in silicon and to enable the first solid-state amplifiers, as summarized in Bardeen's Nobel lecture in 1956 (*11*). Work in just the past 10 years has established the utility of similar electrolyte gate electrodes in printed and organic electronics (*12*). More recently, demonstration experiments showed that deformable ionic gels can serve as elements of high-performance, stretchable graphene transistors (*13*).

In the context of biomedical devices, related types of gels are already in widespread use for low-impedance interfaces between metal electrodes and the surface of the skin. One vision for system design might strategically combine both electronic and ionic modes of operation, in which the latter enables conformal electrical interfaces to biological tissues and provides soft mechanical actuation and sensing, whereas the former affords signal processing, control, acquisition, data storage, and transmission. Developing an associated base of fundamental knowledge in materials and device designs represents a promising direction for future work.

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PSYCHOLOGY

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Poverty's mental toll might explain its connection to unhealthy impulsive behaviors.

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Few people wish to be poor. Many find it puzzling that those in poverty seem to get stuck in that state, even when there are opportunities to improve one's lot. On page 976 of this issue, Mani *et al.* (*1*) provide a possible reason: Poverty-related concerns impair cognitive capacity. Simply put, being poor taps out one's mental reserves. This could explain data showing that the poor are likelier than others to behave in ways that are harmful to health and impede long-term success—in short, behaviors that can perpetuate a disadvantaged state.

The eye-opening study of Mani *et al.* included laboratory experiments and field studies that tested the "cognitive constraint" hypothesis. One experiment gave individuals who were poor (defined by household income) hypothetical financial decisions, followed by tasks that measured mental abilities. Poor people who earlier had contemplated a difficult financial decision showed worse mental performance than others. A study of farmers demonstrated that the mental acuities of the same person varied with swings in income. Farmers were given challenging cognitive tests before and after harvest. Before harvest, the farmers experienced much financial strain, whereas after harvest (and the receipt of payments), they did not. The results showed clear and demonstrable improvement in cognitive capacity after harvest. This outcome held after accounting for the stress of pre-harvest periods. The authors propose that poverty imposes a cognitive load, which impairs cognitive capacity.

The depletion of mental functioning with poverty comports with a framework called the limited-resource model of self-control. Failures of self-control are implicated in some of society's most pressing problems,

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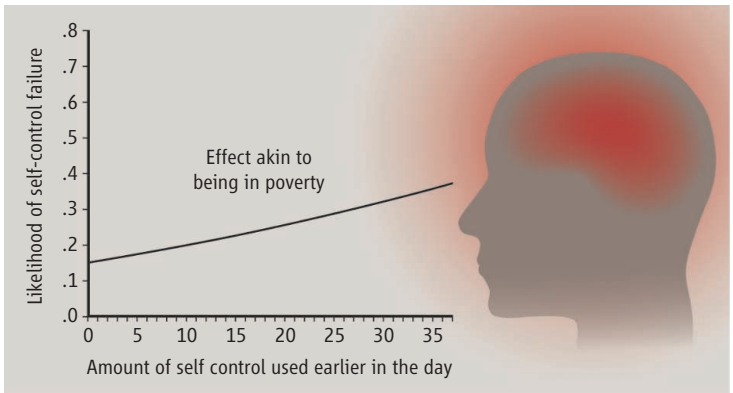
including poverty (*1*–*6*). When people want to reach a goal, they use self-control to produce responses and behaviors aimed at moving themselves from the current (undesirable) standpoint to the preferred state. This powerful process, however, is not used as often as it should be. One reason is that self-control is a limited and depletable resource (*7*). When people use self-control, it is like top-flight running for a cheetah, in which a brief period of exertion results in exhaustion.



Mental toll. People become progressively worse at self-control the more they have engaged in self-control previously. The more that people used self-control not to give into desires earlier in the day, the more likely it was that a desire impelled an impulsive behavior later in the day. This situation is akin to poverty, which requires that people often battle back desires. Adapted from (*12*).

Everyone must regulate eating and spending, and wearing down self-control resources leads to detrimental behaviors for both. In one study, people made to resist the lure of delicious chocolates later showed worse performance on demanding mental tasks and at managing negative emotions. Moreover, it led to overeating unhealthy foods (*8*). In another situation, participants were given cash to spend or keep. Those who earlier had used self-control to suppress unwanted thoughts later spent more money and reported stronger desires to spend all the newfound cash. The depletion of self-control ability led to unwise spending (*9*). Both examples suggest a vicious cycle: Overcoming urges and making decisions can deplete mental resources, which in turn can lead to problematic behaviors. Because the poor must overcome more urges and make difficult decisions more often than others, they are more likely to overeat, overspend, and enact other problematic behaviors.

Self-control may be the greatest human strength (*6*) because it is involved in the ability to make wise choices. Several studies have found that after using self-control (and thus reducing the resource), decision-making patterns shift toward favoring intuitive over reasoned options (*10*). For example, options were constructed so that they were extreme on some dimensions (e.g., expensive and high quality) or balanced (moderate price and modest quality). Choosing the latter reflects the use of deliberate cognitive strategies to accept trade-offs. Those who earlier had engaged in self-control activities preferred extreme options that required fewer trade-offs. Moreover, the process of making trade-offs itself requires self-control (*11*). These findings suggest that decisions requiring many trade-offs, which are common in poverty, render subsequent decisions prone to favoring impulsive, intuitive, and often regrettable options.

Regulating urges and desires, even basic ones such as for sleep and leisure, exacts a cumulative effect. Researchers surveyed people seven times a day for several days, tracking their recent desires, attempts at resistance, and whether they performed behaviors implied by the desires. In line with the limited-resource model, people became progressively worse at self-control the more they resisted unwanted desires (*12*) (see the figure).

Chronic pain may be analogous to poverty (*13*) as these patients' behaviors parallel those seen by Mani *et al*. Patients with fibromyalgia, a chronic pain disorder, performed a task that either did or did not require focused attention (comparable to the focus required to drive during pummeling rain, for example). Afterward, they were given a challenging cognitive task. The outcomes were striking. Patients with chronic pain had poor cognitive performance regardless of whether they earlier had used self-control or not. By contrast, healthy individuals showed the standard depletion effect of worse performance only after previous exertion of self-control. These findings imply that there may be entire segments of people who, like the poor and those chronically in pain, suffer constant self-control depletion.

The limited-resource model of self-control points to the following state of affairs for people in poverty. Resisting urges and controlling one's behavior drains self-control resources. The poor must resist and control more than others because they have less money, food, and expendable time. Such limited supplies demand trade-offs, and hence many decisions. And, there is a snowballing, adverse effect of engaging in self-control on subsequent self-control capacity. Altogether, these processes spell a dwindling supply of self-control with few chances to recover.

Governments and organizations must recognize that the lives of the poor are filled with land mines of desire, trade-offs, and self-control dilemmas. Paring down the sheer volume of decisions that the poor must make—perhaps through defaults—and allowing others to share in the decision-making process could help. Scheduling interviews and appointments earlier in the day could be beneficial because people generally possess greater cognitive capacity at that time (*12*). Public settings that require individuals to handle forms, rules, and decisions could have a care area for children to minimize competing demands on attention.

Recent estimates show that about 20% of the world's population is in poverty (*14*). Although that is half of what it was 20 years ago, it is nonetheless a huge number (*14*). Economists are fond of the theory that the more people on Earth, the better, because people create ideas. With more people come greater odds of discovering the cure for cancer, renewable energy sources, or how to cultivate world peace. That premise rests on the notion that all people have adequate mental capacity, a premise now called into question by Mani *et al*. for a fifth of the world's population.

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