The Science of the Mind: 2001 and Beyond

EDITED BY

Robert L. Solso
University of Nevada, Reno

Dominic W. Massaro
University of California, Santa Cruz

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Empowering People Through Friendly Technology: Psychology in the Twenty-first Century

GORDON H. BOWER

n this chapter I present some speculations regarding what people in Western civi-zation might be like a hundred years from now. This is a matter of some curios-y to contemporary psychologists as well as of great concern to those future psy-ıologists who will study these people and treat them for their psychological oblems. Although people are assuredly limited by their biology and brain in hat they can do, I believe that technological innovations of the coming century ill greatly expand the power of individuals to control their environment, to con-ıl themselves and guide their children, and thereby to better direct their own stiny. As a consequence of this greater power, people will be better able to ıprove the quality of their lives, and increase the intelligence, creativity, and ımanity of themselves and their children. It is my contention that psychologists ll play a pivotal role in helping design such technologies to be "user-friendly," field-testing their efficacy, and in refining the technological designs until they hieve a proper fit to the capabilities and talents of individual users. That, at ıst, is the hope that I express in the following pages.

Pitfalls in Predicting the Future

ıny profession knows the hazards and pitfalls of predicting people's moment-to-ıment behavior, it is assuredly experimental psychologists. Even in their closely ntrolled laboratory experiments, psychologists are continually frustrated by their led predictions about human behavior. Therefore, it borders on some unholy version of our professional upbringing to try to predict what people will be like ıundred years from now. The request to speculate upon the distant future is like eiving a license to write science fiction and fantasy. The challenge is also a bit imidating because gazing into a crystal ball to forecast the future is a bit like

taking a Rorschach projective test. There are so many trends to extrapolate, so many things to see out there, that whatever one selects to discuss reveals a lot about the concerns and values of the writer.

In writing of the future, authors can either extrapolate current trends to their likely conclusion, whether or not the outcome is desirable, or they can commingle their forecasts with their wishes and value judgments, suggesting changes they would like to see come about. Because people differ considerably regarding the ideal state they would have humankind strive to achieve, it is fitting that some of the values of psychologists be stated at the outset.

Psychologists' Values

By professional selection and trained indoctrination, psychologists, when viewed as political animals, are basically social liberals, reformers, and caregivers. We see lots of suffering people with lots of problems in living. As a group we are trained to help the sufferers with their problems so they can lead happier, more fulfilling lives. Our collective urge to help people resolve personal and social problems stems from a utilitarian moral base—namely, that one's actions are to be judged according to whether they increase the welfare of the general population. But the notion that psychologists can often ameliorate people's behavioral problems is founded on the belief that humankind—or at least humankind's behavior—is changeable, malleable, and improvable. While we view the individual human life as precious, we also value individuals as members of a universal human culture and civilization that is worth preserving.

Universal Laws of Human Nature?

Psychologists hold nearly contradictory beliefs about people. On the one hand, we recognize the nearly infinite diversity of individual personalities; on the other hand, we believe in certain behavioral constraints and "laws of human nature" (regarding perception, memory, reasoning, etc.) that apply universally, regardless of the gender, ethnic background, or nationality into which one is accidently born.

Social Differentiation

Infants the world over are born with gene combinations and uterine environments that provide tremendous diversity in their propensities for developing differing cognitive abilities and personality traits. The infant's caregivers and early trainers produce a continual bombardment of cultural experiences that assail and buffet the infant through a process of profound social and individual differentiation. This sociocultural environment produces vastly different experiences during children's most impressionable ages of development, resulting in vast differences in personal learning, knowledge, habits, skills, values, and personality traits. The social culture determines the "content" or substance of what is learned, and thereby deter-

mines which emotional adjustments, perceptual–motor skills, and cognitive abilities are emphasized for training.

Universal Constraints on Human Behavior

While recognizing the diversity of human personalities, psychologists also persist in the belief that certain universal constraints or limits on behavioral and cognitive capacities exist and that certain invariant "laws of human nature" apply to nearly everybody.

Many of these universal laws characterize *Homo sapiens* as an intact species produced by biological evolution. For example, because humans share similar bodies and physiology, they all need to maintain their body temperature within a narrow range, and they need to breathe oxygen, ingest nutrients, eliminate bodily wastes, and so on. But exactly what nutrients are ingested—when, where, how prepared, and with what rituals—varies enormously according to one's culture. Thus, whereas physiology determines general needs, the way in which those needs are satisfied varies with environmental and cultural factors. For example, local climates and cultural customs dictate the kind of clothing we wear or the shelters we live in.

Similarly, biological needs such as securing food, shelter, and protection from predators were probably the original bases for many of our social customs, such as the formation of families, clans, and communities, the division of labor, and the specialization of skills of production (into hunters, farmers, builders, warriors, etc.). Because people living in groups often need to coordinate work and social activities, systems of speech communication have developed; and fluency in speaking is acquired according to more or less the same timetable by all children throughout the world. I believe that these universal facts about behavior are not going to be altered by technological innovations of the future.

Universal Limits on Cognitive Capabilities

Just as our shared biological makeup imposes certain requirements on our bodily functions and limits our physical achievements (we can't run 10 miles in 15 minutes or lift 2000 pounds), so also do our nervous systems and brains impose limits on us. Theories about the "architecture of cognition" attempt to describe some of these limitations and constraints (Anderson, 1983; Newell, 1990). For example, psychologists believe that people have a short-term memory of limited capacity which serves as a small workspace (also called "working memory") for storing information and for carrying out the cognitive operations required by mental problem-solving sequences (e.g., adding several two-digit numbers in your head). This working memory has access (through content-addressable associations) to a vast collection of personal knowledge stored in a large, passive, long-term memory. Relevant knowledge in long-term memory can be "activated" and brought into working memory as it is required. For example, in the middle of some mental calculation you may activate the retrieval query, "What's the sum of 3 + 7?" and your memory answers "15."

Because short-term memory has a very limited capacity, we are practically forced to carry through most complex mental calculations or problem-solving sequences one step at a time in serial order. Although our sensory receptors (ears, eyes, etc.) can take in large amounts of sensory information at once through parallel processing, that overload is of little use because it fades away very rapidly unless it is attended to and recoded into something memorable. And our attention span is severely limited, perhaps to only one or two "items" at any given moment. People can appear to attend to several sensory channels at once only by rapidly switching attention among the sensory images residing briefly in a sensory memory. This happens, for example, when we listen in on several conversations at once.

The capacity limitation on attention appears to be structural (hardwired into the mammalian brain) and is rarely modified by extensive training. Rather, through training, people can learn how to better reduce distractions and better concentrate on relevant information; they can learn how to repackage lots of information into single "chunks" that take up less space in working memory but nonetheless serve as "proxies" that point to large collections of information in long-term memory.

Constraints in Cognitive Architectures

I mention such structural features of cognitive architectures to point out that most cognitive psychologists would maintain that these kinds of capacity limitations within working memory are nearly universal and invariant across cultures and across centuries. Although the capacity varies somewhat across individuals (and correlates with reading comprehension and reasoning ability), it probably exhibits similar ranges across cultures and across time. Brain injuries, strokes, and some degenerative brain diseases often reduce working memory capacity, resulting in a variety of related deficits in carrying out everyday cognitive tasks such as keeping oriented in time and space, tracking conversational topics, and speaking coherently.

The built-in constraints on cognitive architecture limit what people can or cannot do. Let us consider just a few of these limitations. For example, people can take in and store new information at only a certain, relatively slow rate, and attempts to speed up that intake, say, by computer-compressed speech, have had only limited success. We suffer interference and forgetting of information briefly attended to, and we have only limited means to overcome that inexorable process. We can usually think of just one "thing" at a time, and we are unable to hold in mind a lengthy chain of reasoning. When making a complex decision about which house or car to buy, which job to take, we are usually frustrated because we cannot keep in mind all the relevant factors to be considered for all the possible options. Instead, we fall back on a few factors in determining our decisions. Consequently, our decisions are much affected by irrelevant factors such as the salience or availability of particular kinds of biasing information. As a final example, our moods and emotions color our thinking, our ways of interpreting the social world, ourselves, and our own actions, biasing the kinds of memories and

interpretive categories that come to mind as we canvas the library of our mind for an opinion; and these biases often arise in subtle, unconscious ways.

These kinds of influences and constraints are universal, shared by all people, and presumably have been present since time immemorial. They are likely to continue as mental governors constraining the thought processes of our distant descendants well beyond the twenty-first century.

Technologies To Overcome Constraints

Despite the kinds of constraints enumerated here, I nevertheless still believe that in the coming century, clever inventors will fabricate technological protheses (extra "cognitive hands") that will help humankind overcome at least some of the limitations imposed by our biology.

Consider just one example. Hitherto, a person's intelligence was considered to be a stable ability residing "in" him or her; but increasingly, we are coming to view intelligence as partly residing in the environment—or, rather, in the way people arrange the environment around themselves to promote and support intelligent actions. In the future, a larger part of that intellectual environment will be technological and probably machine-based.

Just as the invention of the automobile helped humans move faster over longer distances, so has the invention of computers enabled us to think faster and more accurately over longer chains of reasonings. Just as paper and pencil enabled the architectural designer to draw different plans for a building, so have computer-assisted video displays enabled modern designers to visualize buildings in three dimensions, to see through structural barriers, to rotate the angle of viewing, to alter a few parts to examine quickly their widespread effects throughout the entire building, and so on. Such computer graphic displays illustrate the power of a technology that allows people to externalize the products of their thought processes, to build visual displays that model some reality, to display symbolic models which they can manipulate and judge on the graphics terminal. In this manner, thinkers can use the power of visual pattern recognition to enhance their otherwise limited ability to reason with words and symbols.

Reshaping Humankind

One can look upon the history of science as our species' attempt to predict and control nature; for psychologists and social scientists, this includes most especially human nature. Technology holds out the prospect of enabling people to control better their physical and cognitive environment and to solve more easily the problems it poses. In this manner, people should be able to follow a better planned life and attain more predictable outcomes. Of course, all this requires that we in some way "reshape" human behaviors, which is my next topic.

There are four primary ways to reshape human actions: (1) alter their genetic makeup; (2) change their technological environment; (3) change their learning environment and learning experiences; and (4) change their motivations. I shall first discuss the reshaping of humankind's genetic makeup before moving on to the last three topics, which might be thought of as a reshaping or engineering of people's behavioral environment. In most cases, I shall simply be extrapolating some likely future consequences of the current direction of research knowledge, and I do so without gainsaying whether certain changes would be ethically acceptable, politically correct, or politically feasible during the next century.

The Eugenics Program

The idea of improving humans through genetic engineering is the program of *eugenics*, an ancient idea that was suggested by the success of animal husbandry. The scientific underpinnings of the eugenics thesis have been known for centuries, ever since herdsmen selectively bred cattle, camels, horses, and domesticated fowl to maximize properties in the offspring. The scientific basis is now understood in even greater detail owing to major advances in molecular genetics over the past thirty years.

Eugenics is the geneticists' contribution to social reform. The problems with the eugenics programs have always been moral and political, and only secondarily scientific. Eugenics got a bad reputation from association with the Nazis and other fascists who wanted to impose their view of human genetic perfection (i.e., the Aryan race) upon the rest of the world, and in the process "cleanse" the rest of us.

We strongly and rightly reject the idea that some central governmental agency should be given the power to decide for all of us what human qualities should be fostered. However, the possibility of such governmental abuses does not mean that prospective parents of the future should not have some control over the kind of children they bring into the world. Ask any prospective parents for their preferences regarding their child, and most will agree that they want their child to be physically and psychologically "healthy," energetic, happy, outgoing, sociable, industrious, curious, creative, and intelligent. Of course, within that broad framework, different parents will disagree on the relative importance of, say, conformity versus creativity in their child.

Human Genetics

As the human genome is fully mapped and as human geneticists come to understand better the manner in which gene combinations are expressed in human phenotypes and behavior, the time will probably come when many genetic diseases (both physical and psychological) can be detected early in pregnancy (say, within six weeks of conception) and hence (at the parents' option) the embryo can either be repaired quickly by recombinant gene-splicing or be aborted if that is acceptable to the parents and society.

In this manner, society should be able to reduce the frequency of the genetically determined "psychological" maladies such as autism, severe attention-deficit disorders, severe mental retardation, familial dispositions toward Huntington's dis-

ease, epilepsy, schizophrenia, manic-depressive disorders, Alzheimer's disease, and other such afflictions. Although the diathesis–stress model of mental disorders is doubtless correct in emphasizing the interaction of both environmental and genetic factors in causing mental disorders, the fact remains that a person's genes determine his or her susceptibility to developing a mental disorder when confronted with the unavoidable stresses that arise in nearly all modern lives.

In principle, the human geneticists of the distant future, as did those in Aldous Huxley's classic *Brave New World*, will have the ability to manufacture and combine human eggs and spermatozoa that yield embryos having some specific combination or profile of physical and general psychological traits that the parents can select. The traits that could be genetically selected would be relatively general ones such as extroversion, industriousness, or sociability. Of course, the manner and content with which such broad traits are expressed in behavior would be determined by the child's social learning. That is, an industrious child might become a corporate magnate in Germany, a scientist in Bolivia, a rug merchant in Morocco, or a drug smuggler in Miami: The trait means simply that whatever they do, they will work hard at achieving whatever ambitions their culture reinforces.

Several alternative methods are imaginable. By one method, the father and mother would supply the sperm and egg which would be taken to the genetics lab, examined and selected for absence of defective genes, then combined to produce an embryo. Early in gestation, the embryo's chromosomes would be checked and, if not developing properly, altered so as to produce an embryo closer to the desired genotype.

An alternative method would completely synthesize the chromosomes and genetic material for an embryo by following different biochemical prescriptions. This method is probably unrealistically complex for the near future.

Moral and Legal Complications of the Eugenics Program

The biochemical synthesis procedure briefly mentioned here has the feature that the fetus would have no biological parents, only someone who requested that it be created with certain properties. Because so much common law about children is premised on the idea that every child has parents, the synthetic method would call for radical revisions in laws of inheritance, parental responsibility for child, and other family-oriented customs.

Also, if children no longer were to be created by sexual reproduction, then sex between loving partners could become solely for pleasurable bonding rather than procreation, and that would raise concerns among certain religions which maintenance sexual behavior only for procreative purposes.

The ability to select general traits, sex, and physical characteristics of one's children brings to the foreground the moral issues of deciding what kind of species *Homo sapiens* should become. By leaving the decision mainly in the hands of the parents, the species will be assured of at least some measure of genetic variability and biodiversity. The fear would be that successive generations would drift in the

direction of some paragon image popularized, say, by Hollywood and the media, so that everyone would look like popular film stars, or similar ethnic beauties. A possible outcome of such genotypic sameness is that the species might perish either from sheer boredom with one another's appearance and personalities or from overwhelming new challenges.

One possible challenge is that new virulent bacteria or viruses could arise that could successfully attack the engineered genetic strains that might lack the relevant immune responses. One could argue that evolution, in its infinite wisdom derived from millennia of genetic experimentation, has created just the right range of genetic variability among humans so that the species can survive nearly any onslaught from the myriad forms of bacteria and viruses that inhabit this planet. Perhaps, by selectively tinkering with that range of evolved genotypes, our human genetic engineers would be visiting upon us a host of unanticipated diseases against which our species would have no adequate defense.

Designing Our Own Milieu

Besides having the prospect of designing the genetic makeup of their children, the people of the late twenty-first century should be better able than us to encourage, moderate, and support their behavior by controlling their environment. New tools and inventions should provide people with powerful means for achieving their goals and avoiding the deleterious consequences of technology.

A simple example of how technology could reduce personal frustrations comes from the area of weight control. Medical science tells us that obesity is a serious health risk, especially when combined with high levels of serum cholesterol. Yet, despite struggling with unsatisfactory diets, many people in our society are overweight. The problems of being overweight could be greatly ameliorated if food companies of the future had incentives (i.e., profits) to invent and use artificial fats and sweeteners that provided highly palatable substitutes for the high-calorie, high-fat foods we presently eat. At present, food companies use "popular demand" and the profit motive to justify feeding consumers the unhealthy junk foods that keep so many addicted to sugars and fats.

Another example of environmental manipulation in the future would be the self-conscious design of one's own work-space. Corporate executives, scholars, bureaucrats, scientists, and many others spend large portions of their work day at desks, reading reports and writing or dictating reports and correspondence. A major problem for such workers is getting access to relevant information in a timely fashion. The tools of information technology—computers networked into large document-sharing data bases; CD-ROMs containing hundreds of complete technical encyclopedias; video disks with thousands of motion-picture or video illustrations—all will be expanded in power, made more user friendly, and permeate the work sphere of everyone. A small example familiar to psychologists is the *PsychLit* CD-ROM program of the American Psychological Association which lists titles, authors, and abstracts of most papers published in a large number of professional psychological journals and books.

A major challenge for psychologists of the future will be to design such infor-
ation resources so they are optimally usable by everyone. People will have to
specially trained to scan large volumes of information quickly to extract the
levant bits for their immediate needs. Education of the future will be largely
›-based and expertise-simulating rather than vast memorizing exercises: On-the-
› trainers will be teaching students how to reason about problems in their spe-
ılty and how to search for answers to complex questions by perusing vast pools
technical literature. Cognitive psychologists will design various "thinking tools"
the computer to prompt the expert through a series of questions regarding
ne case or problem he or she is pondering. Automated abstracting services will
used increasingly to help knowledge-intensive professionals (such as scientists,
ineers, physicians, lawyers, etc.) keep up with new information published in
ir fields. Very probably most of the technical literature in the distant future will
published only electronically, not in paper journals or books.

These environmental controls are external to our body—the typical perspec-
. But another entire area for exercising control is within our *internal environ-
nt*. The controls can operate either directly upon the brain or in the body and
endocrine system outside the brain. Let us consider several of these methods
regulating our internal milieu.

nitoring and Controlling One's Internal Milieu

neuropharmacology of mood disorders should be sufficiently understood in
future that scientists will know how to monitor moment-by-moment the levels
irculating endocrine secretions in a person's bloodstream just as an outdoor
mometer continuously measures the outside temperature. In this manner the
ls of circulating cortisol will indicate a person's stress level, blood-glucose
l will indicate hunger level, hormone levels will indicate sex drive, and so
. Similar on-line, plasma-assay techniques should be able to display the blood
l of alcohol for drinkers or the blood level of insulin for diabetics.

These biological signals could be used for several purposes. They could inform
le of their internal states, so that immediate actions could remedy any un-
ed state. For example, the diabetic could be warned to take an insulin injec-
the drinker with high blood-alcohol warned to take a taxi rather than drive
, and the stressed person warned to take time out for relaxation.

f the signals were externalized for others to recognize, they could even serve
ıes for social partners to behave in appropriate ways—for example, to signal
spouse when the partner is exhausted, stressed out, frightened, angry, inebri-
sad, or sexually aroused, and to take appropriate actions to help the partner
fy this disturbance of his or her internal milieu. In these cases the technology
d be allowing us literally to "wear our emotions on our sleeves," so they
l be easily read. Such a system could enable people to have a better under-
ing of and thus be more compassionate toward their friends and loved ones.
ourse, enemies could use the signals to exacerbate the emotional disturbances
verse directions.

Automated Homeostasis?

Some corrective actions of a biochemical nature, to rectify a hormonal upset, could perhaps be programmed to occur automatically through the use of a small computer-pack and an in-dwelling cannula with a "cafeteria" of synthetic endocrine agonists (or antagonists) that it could perfuse into the person's bloodstream. Each person's computer-pack might have stored a personally optimal "set point" for each circulating substance, and it would perfuse appropriate amounts of agonists or antagonists for that substance in order to maintain its monitored level near that set point.

Automated Medication Regimens

Such perfusion systems would also be very useful for reliably delivering medication to medical patients such as those afflicted with diabetes, heart disease, or thyroid deficiency. Something of this kind would be useful, too, for the delivery of psychoactive medications to chronic schizophrenics, depressives, and manic depressives. Current psychiatric practices with oral medications increase dose levels only very gradually over three to eight weeks, and are monitored weekly for unwanted side effects. As a result, psychiatric patients often become discouraged by the lack of immediate improvement in their functioning, so they stop complying with their prescribed medication schedule. Such noncompliance creates difficulties for the therapist who is trying to arrive at an optimal medication schedule for the patient.

A continuous monitoring system could overcome some of this problem by testing the level of drug (or drug metabolites) in the bloodstream and distributing the drug to reach a target level quickly. The target dosage would be adjusted by the physician who would be taking account of the patient's psychiatric symptoms along with the patient's judgment of well-being and negative side effects.

Monitoring Brain Neurotransmitters

More technically difficult would be a similar system designed to monitor the levels of effective neurotransmitters in the brain, such as dopamine, epinephrine, norepinephrine, serotonin, and other neuropeptides. The levels of these neurotransmitters might indicate or predict people's general mood—whether alert or sleepy, depressed, anxious, or relaxed—perhaps even before they are aware of their mood. The signals reflecting the level of different brain neurotransmitters could again be used with a computer-controlled, subdural system that feeds neurotransmitters into a carotid artery. The system could contain a negative feedback circuit to maintain specific target levels of brain neurotransmitters, by perfusing agonists or antagonists to raise or lower the imbalanced neurotransmitter. The administered drugs and chemicals would have to be altered so they could pass the blood-brain barrier—the body's means of blocking foreign chemicals from entering the brain.

People would be able to regulate their moods to some extent by programming into their perfusion pack different set points, to keep them alert, nonanxious,

nonhostile, and nondepressed. In fact, people could experiment until they discovered that combination of neurotransmitters in particular brain regions that produced for them a panoply of feeling states, from alertness to sleepiness, from euphoria to calm relaxation. Such personal data could enable them to "dial up" any particular feeling state that they considered appropriate for the situation they were entering.

Some obvious governmental controls on the manufacture and distribution of relevant biochemicals would have to be designed into supplies for such systems to prevent their abuse. Conceivably, some people might try to "tune in and drop out" by maintaining an intense cocaine high most of their waking hours. Our society's present inability to control illicit drug trafficking and drug abuse does not augur well for the success of such drug-control programs. But a few methods have been successful, and they will be discussed now.

Treating Drug Addictions

It is generally believed that the most efficacious treatment currently available for severe heroin addictions is sustained methadone maintenance (Kreek, 1993). A significant level of methadone in the bloodstream accomplishes two ends: first, it eliminates or relieves the aversiveness of the usual withdrawal symptoms; second, it blocks the euphoric high that usually accompanies another heroin injection. Many methadone-maintained addicts falter and try a few more heroin injections in search of the euphoric high they experienced before; but with the methadone blocker, they get no high, and the conditioned link between an injection and euphoria weakens and eventually extinguishes.

A major stumbling block in our society is getting enough addicts into methadone treatment and keeping them on methadone indefinitely. (Evidence suggests very high relapse rates once an addict is withdrawn from methadone.) A technical solution would be to have physicians implant into the upper arm of each convicted addict some subcutaneous, slow-release methadone sticks (much as Norplant, a female contraceptive, is voluntarily implanted in the arms of women). The implants would slowly release methadone at the proper dosage in order to prevent withdrawal symptoms and block euphoric highs. Every few years the methadone would have to be replenished because evidence suggests that methadone treatment should continue indefinitely. A blood-monitoring system would be required to ensure that the addict does not remove the implants.

One can hope that similar therapies will be available to counteract the euphoria or high produced by other abused substances such as cocaine, amphetamine, LSD, alcohol, opium, morphine, and their derivatives. Perhaps the simplest treatment for these at present is to implant in the abuser an in-dwelling, slow-release chemical that causes nausea when combined with the illicit drug. For example, to counter the craving for alcohol (which is the most frequently abused drug), *antabuse* which causes nausea when combined with alcohol could be used. Like heroin addicts, alcoholics might be treated (with their consent) by having slow-release antabuse pellets implanted in their upper arms. In this manner, they would be made sick whenever they drank alcohol and would thereby learn to avoid alcohol. That, at least, would be a possible recommendation from science, for chronic

abusers—say, drunk drivers with repeated offenses. Similar programs could be used to either prevent or cure addiction to cigarette smoking—a major cause of medical maladies. Of course, all of us can think of various practical, ethical, and political obstacles to such programs.

Treating Sleep Disorders

One hope is that the neuropharmacology of sleep will be understood sufficiently in the future so that psychologists will be able to alleviate certain sleep problems, especially insomnia: problems in falling asleep, depth and quality of sleep, or early-morning awakening. Perhaps by self-administering an appropriate sedative into the carotid artery, people could put themselves immediately into a restful sleep; and by setting a timer, select a sleep duration after which time an "awakening" antagonist would be perfused into the brain to bring on wakefulness.

Another desirable invention would be an artificial light box that travelers could enter briefly to accelerate their adjustment to the large day–night changes that can cause jet lag. At present, adjustment to jet lag due to long-distance travel is a slow, frustrating process; in a futuristic business environment requiring frequent long-distance trips, quickly resetting one's biological clock to track the local time would be a much desired goal. The method could use either internal electrical or biochemical stimulation of the suprachiasmatic nucleus, or external stimulation provided by a pulsed light box. By sitting for several minutes in the light box, travelers could have their biological light-dark cycles set to the local period. Such light boxes would be available for travelers at every airport, in airplanes, or in hotels catering to long-distance travelers. Such devices would be useful, too, for nightshift workers who often experience difficulty adjusting to working during darkness and sleeping during daylight hours.

A major obstacle to controlling beneficial sleep is that we do not presently understand much about what causes sleep or what biochemical functions it accomplishes. The cycle of "fatigue–sleep–revitalization" suggests that sleep is brought on by the accumulation of certain neurochemicals at particular brain sites, and that these are metabolized or cleared away during sleep. Clearly, however, the process is not totally "biochemical" because mental activity and anxiety can keep us awake and mental relaxation helps put us asleep. Nonetheless, as we come to understand more about the biochemical changes involved in the "refreshment process" of sleep, scientists of the future might be able to devise "instant refreshment" pills or injections that would have the effect of quickly providing the biochemical changes in the brain that currently can now be provided only by several hours of restful sleep. The refreshment injections would probably be combined with psychological procedures to relax and clear the mind. Such refreshment procedures would be especially helpful for doctors, paramedics, pilots, and combat soldiers who must stay alert long hours without a break for sleeping.

Sensory Augmenters

As our understanding of the physiology and psychology of sensory systems increases, so should psychologists and engineers become better able to design trans-

cers that can either augment sensory receptors or shunt or replace defective es. Today's augmenters are external amplifiers such as hearing aids or specta- s. Future augmenters might be implanted surgically, such as a new corrective ıs for the eye or new tympanic-membrane amplifiers for the hearing-impaired. ese would replace the external hearing aids and spectacles commonly used to- y, and would have primarily cosmetic and efficiency benefits.

The more difficult problem would be to restore vision to people who have had inal degeneration or to restore hearing to people who have suffered degeneration damage to parts of the middle or inner ear, or to the auditory pathways. In nciple, a diaphragm could be mounted in the external ear to transduce sound- ssure signals similar to the transduction provided by the tympanic membrane; se signals could be relayed to an in-dwelling microchip that analyzes, then ısforms, the sound pressures into a pattern of electrical impulses through a ıdle of, say, 100 electrodes connected to different fibers of the auditory nerve. this manner, the microchip would stimulate the auditory fibers to mimic the 'r firing pattern normally caused by vibrations of hair cells located along differ- regions of the basilar membrane. The job for auditory psychologists would be ıelp acoustic engineers select and test the significant acoustic parameters, say, n speech, that will provide maximal discrimination of the sensory information. Perhaps something similar could be devised to replace a defective retina to augment pattern vision, but the complexity of circuitry in the retinal ganglion :r suggests that the engineering task would be immense. Nonetheless, human ors psychologists might be able to design less than optimal, artificial retinas would extract sufficient information from the visual array to help a visually aired person move around to a significant degree.

Other obvious sensory augmenters would aim to create "supranormal" effects, ı as allowing us to amplify weak visual or auditory signals. For example, ıan factors psychologists working in the auto industry could develop "night gles" for auto drivers or appropriately treated windshields that would amplify trast signals from visual-object patterns, thus enhancing their recognizability ng night-time driving. Another sensor on the front of an auto could inform the er of the distance to some roadway object ahead, the closing speed, and the nated time before meeting. Such information could be used further by a mi- hip to calculate and signal drivers whether at current speed they have suffi- t time to pass one road vehicle before reaching a second, oncoming vehicle.

Turning to a consideration of sensory pain, the goal of a sensory transducer ıld be to reduce or antagonize the pain sensations. One method for controlling ıatosensory pains, say, that from an inoperable tumor pinching a nerve, would o reduce the neurochemical substance in the dorsal spinal roots that carries sensations while encouraging at the same time the release of endorphins. A ınd method would be to use subdural electrodes to augment the firing of pain bition circuits in specific regions of the brain (periaqueductal gray area and ıé nuclei of the medulla; see Pinel, 1990). A third method would be to intro- into these areas opiate-like substances that block or antagonize pain signals. ırth method would be to develop further psychological techniques for reduc- pain, including cognitive restructuring, distraction, and sensate imagery.

Enriched Learning Environments

The schools of the future, if there are such institutions, will use more intelligent computer tutors with thousands of audioisual aids on CD-ROMs. The computer tutors would record the progress of each student in each subject matter, keep track of his or her skill level and learning strategies, and design individualized instructional materials appropriate for that student's profile. Students would progress through a collection of materials at their own rates and in a sequence determined partly by their interests along with inherent logical sequencing of the subject matter. Teachers and students' parents will largely play the role of cheerleaders, motivators, and guidance counselers rather than drill instructors for their students.

Schools of the future will expend far more effort to interest or motivate students to learn the material being taught. This will often be done by teaching concepts with entertaining visual illustrations and "real-life" contexts that connect the interests of the learners to the subject being taught. Real-life uses of the knowledge would be illustrated with video clips of people who use that knowledge or skill in their job or daily chores. Using what psychologists have learned about motivation and learning, the material to be learned would be presented in the context of a dramatic narrative that ties together items from diverse lessons such as math, physics, biology, and accounting. Such material would be integrated with the students' everyday life as far as possible.

Moreover, the presented material itself would be organized into tree structures or diagrams that brought out the logical dependencies among the concepts and principles, all with the intention of emphasizing the students' meaningful understanding of the material. In other words, the implementation of the educational curriculum would be based on principles gathered from basic research on learning and memory.

Memory Aids

Techniques that enhance the amount of information we can learn will be developed and disseminated more widely in the twenty-first century. Students in school will be taught not only the content or substance of the material, but also mnemonic techniques and devices—in other words, learning aids—that will enable them to absorb material more quickly and retain it longer. Textbook writers and newspaper reporters will present content in an organized fashion with many mnemonic aids to facilitate learning of the important points.

Similarly, the aging population of the twenty-first century will have the use of mnemonic techniques and devices that will help them avoid age-related declines in memory. Psychologists have already designed a collection of mental training exercises that could be put to greater use by the elderly. These exercises are designed to challenge and extend gradually the mental abilities of the elderly. A battery of exercises in concentration, visualization, relaxed alertness, reduction of test-anxiety, problem-solving, and so on, could be provided in graded doses to people of different ages as mental prophylactics against the usual ravages of an inactive, aging mind.

Smart Drugs

In addition, advances in the neurophysiology and neurochemistry of learning will undoubtedly help improve human memory. Several drugs have been found that improve simple learning, even when given shortly after the learning episode (McGaugh, 1989). These drugs appear to work by enhancing the extent and permanence of biochemical changes at the synapses of the brain circuits involved in representing the learning episode. To date, such facilitation has been found mainly for a few selected compounds given to enhance simple conditioned aversion in rats and mice. But the hope is that future psychological research will discover inexpensive drugs that will facilitate more extensive and complex learning in humans.

One impediment to school learning in young children is the syndrome of poor concentration and hyperactivity known as "attention-deficit disorder." Whether or not this is a coherent syndrome, the label nonetheless points to behavioral deficits in precursors of learning, so that a typical consequence is poor learning and below-grade academic achievement. Treatments for attention-deficit disorder include both the psychological and the pharmacological. Ritalin and other such stimulant drugs have the paradoxical effect of quelling the hyperactivity and apparently increasing the child's compliance with classroom routines. Future psychologists should be able to develop effective techniques for training such children to maintain attention or concentration on learning materials.

anguage Learning

he future will bring an international diversity to science, business, and cultural fairs, and our descendants will have to deal with the problems created by attent int linguistic diversity. Techniques to enhance learning of language could be veloped and applied more broadly in the twenty-first century. It is commonly lieved (though disputed) that very young children learn a second language more sily than do adults who have been reared with only one language. The apparent vantage could be due to children's usually total immersion in the language cul- re they are learning and also the simplicity of children's language. Whatever the act reason for the advantage, we might capitalize on the enhanced language- rning of children by providing immersion training in several languages through- t the first ten years of their lives.

An alternative way to deal with multilingual contacts is for people to wear a nslator-computer in their shirt pocket hooked to an in-dwelling earphone. The teners can dial up any one of a menu of speech translation programs for differ- languages, all being translated into the listener's native language. In that way, h participant in a conversation would be speaking and listening in his or her ive language, with the pocket computers providing the speech-perception-with- nslation interfaces. Perhaps once the language barrier between people is over- ne, we shall be able to concentrate more on the importance of understanding beliefs and psychological perspective of people from other cultures.

Electronic Communication

It is clear that telecommunications will be vastly improved in the future and will affect the way we interact. Each person would carry around a small cellular telephone with a unique phone number. Thus, dialing that number would always contact that portable phone, and the connection could be made over far larger distances than with current cellular phones. The person need not answer every call, but rather could select a mode whereby calls would be shunted to his or her message-recording number, and there prioritized according to the listener-provided information on the importance of the caller or category of caller.

Electronic mail systems will be greatly expanded into every home and office building and will most likely replace the slow mail system we have been accustomed to, except for mailing advertisements. The main innovation is that a speech-understanding system will be put in front of the mailer, so that senders need only speak their message into the decoder for it to be sent electronically either as a voice message or as a "printed" text to the receiver's computer screen.

Telephone and video conferencing will become cheaper and more popular as they increasingly replace physical meetings, especially those where participants travel long distances to a central meeting place. The social dynamics of teleconferencing will become a major topic in social psychology, and efforts will be made to supplement the verbal message with a variety of signals from nonverbal sources, such as the facial expressions and body language of speakers and listeners. Such signals are known to enhance or supplement the message carried by the words alone.

Final Comments

My discussion has touched on probable changes in people's lifestyle that technology might foster by the end of the twenty-first century, changes that psychologists will need to deal with. The so-called "universal laws" of behavior will not change much; that is, if psychologists were to test subjects of the late twenty-first century on standard experimental paradigms (say, memory scanning or short-term memory tasks), they would obtain roughly the same performance as our contemporaries in such tasks. The way in which people of the twenty-first century will differ enormously from us is in their standard technology, which will foster other changes in many of their personal capabilities and attitudes, which in turn may cause corresponding changes in their social beliefs and policies. Psychologists will need to be prepared to deal with the personal problems created by these revolutionary changes in life-style as well as the job stresses that will stem from these changes in personal capabilities and responsibilities.

User-friendly technologies could provide people with many ingenious tools to help them alter their external and internal milieus. In this manner, the technologies could empower people to attain their goals more easily and derive more satisfaction from their work and life pursuits. They would then live longer, happier,

healthier, more productive and creative lives than people do today. After all, isn't that the Utopian goal of all social reformers, including psychologists?

Acknowledgments

The author's research is supported by a grant MH-47575 from the National Institute of Mental Health. However, the views expressed here are solely his own, and the grant from NIMH does not imply endorsement of these views by that agency. The author thanks Sharon Anthony Bower, who provided considerable motivation and input to the crafting of this paper.

References

Anderson, J. R. (1983). *The architecture of cognition*. Cambridge, Mass.: Harvard University Press.

Kreek, M. J. (1993). *Biological basis and pharmacotherapy for addictive disorders*. Speech given at Indo-U.S. Scientific Symposium: Mental Health and Neurosciences in the Decade of the Brain. Bangalore, India. February.

McGaugh, J. L. (1989). Involvement of hormonal and neuromodulatory systems in the regulation of memory storage. *Annual Review of Neuroscience, 12*, 255–287.

Newell, A. (1990). *Unified theories of cognition*. Cambridge, Mass.: Harvard University Press.

Pinel, J. P. J. (1990). *Biopsychology*. Boston: Allyn & Bacon.