SECOND DECADE SYMBIONICS AND BEYOND

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ABSTRACT

Reviewing the last decade's progress towards the symbionic mind-- a sophisticated direct neural interface between the brain and the environment--we speculate that in the future the symbionic mind will used to channel wireless, virtual reality information directly to the cortex, bypassing existing sensory channels. The result will be participation in virtual reality experiences in cyberspace creating seamless, alternate realities indistinguishable from reality. Such eventualities will inevitably lead to innovative altered states, fresh conscious perceptions, new experiences of the sublime, and the possible merging of human realities into a single consciousness, necessitating a redefinition of individuality. More exciting is the possibility of real-time feedback from the cortex through the symbionic mind to constantly tailor virtual reality experiences. Might the functions of our existing nervous system eventually migrate to the symbionic mind to feed the creation of a new personal caretaker--a virtual "guardian angel"--to guide us though the new millennium?

SECOND DECADE SYMBIONICS AND BEYOND

It was at the First Global Conference on the Future held in Toronto in July 1980 that the idea of Symbionic Minds was first presented. In the original paper (Cartwright, 1980a) and in subsequent papers (Cartwright, 1980b; 1983a; 1988, 1989), intelligence amplifiers were visualized connected either directly or indirectly to human brains, capable of independent, intelligent action, existing symbiotically, and making us to some extent, bionic.

Such sophisticated intelligence amplifiers will be significantly more powerful than present day computers and will be wired directly or indirectly to the human brain for both input and output. These brain prostheses will amplify and strengthen all the intellectual abilities we now take for granted as comprising intelligent human activity. They can be called "symbionic" minds (from the words symbiotic + bionic) because of the close, interdependent relationships that will almost certainly exist between them and us, and because they will make us, to some degree, bionic.

It is the design and development of such brain-computer interfaces that comprises the new science of "symbionics". Originally conceived as comprising four independent research areas, the concept now embraces the following seven:

1. emgors,
2. brain pacemakers or cerebellar stimulators,
3. biocybernetic communication,
4. neurometrics,
5. artificial intelligence
6. biotechnology, and
7. virtual reality.

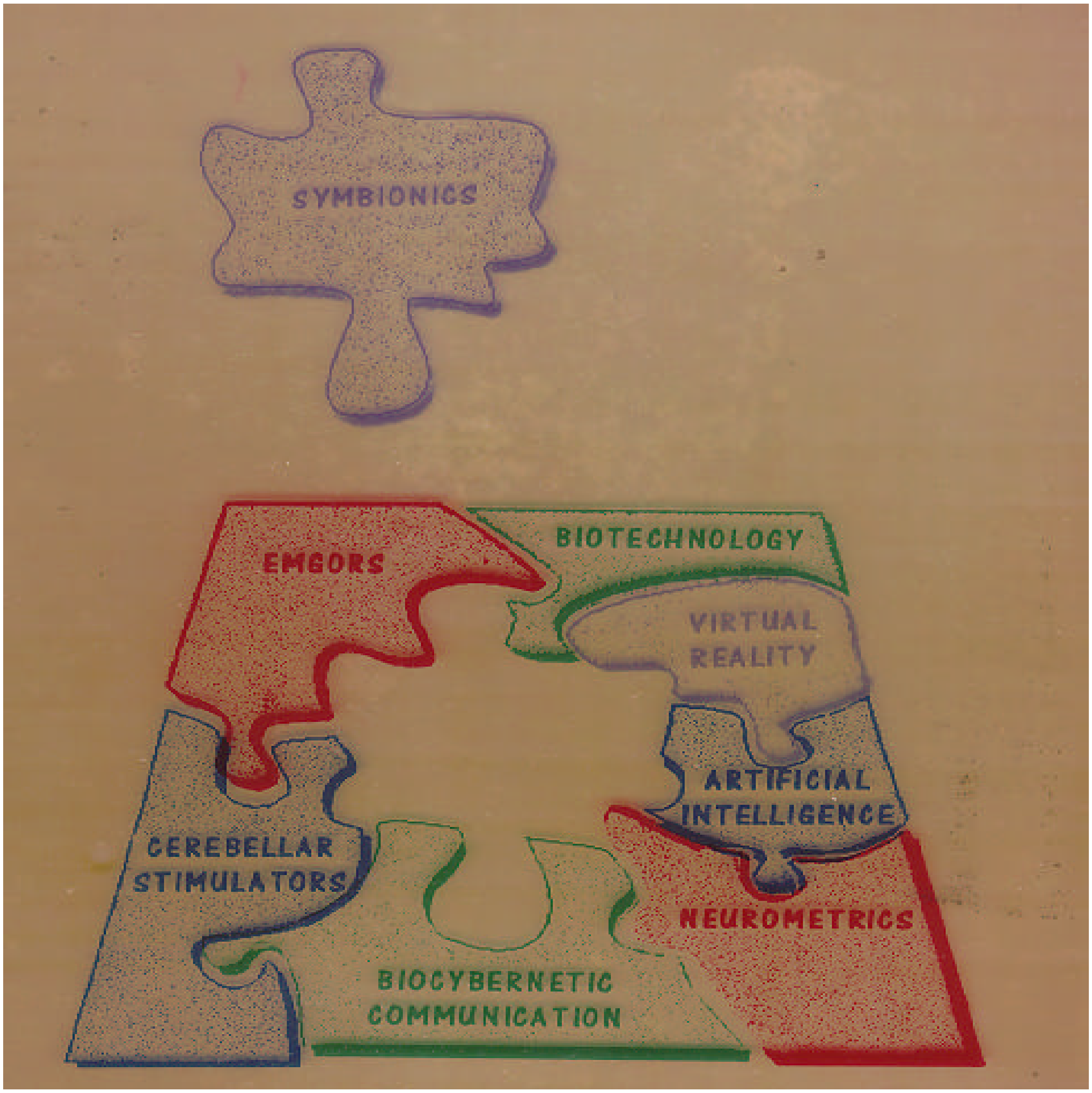

Figure 1 - The Puzzle of Symbionics

1. EMGORS

The first of these is the development of "emgors" (electromyogram sensors) which are now used to enable amputees to control artificial limbs in an almost natural manner. The aim of this research is to create artificial limbs that respond to the will of the patient by finding in the stump of the severed limb the brain's own natural impulse called the myoelectric signal or electromyogram (EMG), improving it through amplification or other means, and using it to control electromechanical devices in the prosthetic appliance. An obvious use would be to have it control an artificial limb called a myoelectric arm (Glass, 1986).

In the last decade remarkable progress in engineering has evolved the crude prosthetic arm into a fully functional artificial replacement. The Leverhume Oxford Southampton Hand has been developed at the Oxford Orthopaedic Engineering Centre as a myoelectric replacement arm for amputees. It is designed to allow the patient adaptive control over hand functions in a prosthetic that resembles the natural model. The Southampton hand can generate a large number of independent movements with a very small amount of user input (Kyberd & Chappell, 1994).

Even commercial companies are distributing myoelectric arms such as the Utah Arm from Motion Control Inc. This myoelectric arm has a near-natural look, feel and use. The Utah Arm can pronate, supinate, be exchanged for other terminal devices and can operate on a small 9-volt battery. Muscular control of artificial devices is a current reality (Motion Control Inc, 1999).

In the future, the same principles may be used to benefit everyone by allowing us to control mentally an extensive assortment of useful devices.

2. BRAIN PACEMAKERS

The second area is in the development of brain pacemakers. One variety of these, known as chronic cerebellar stimulators, followed the creation of cardiac pacemakers and were based on research involving the electrical stimulation of the brain. Chronic cerebellar stimulation (CCS) has been used with children with spastic movements to help them achieve some measure of control over their muscle functions. Such mental pacemakers are now being used to prevent patients from falling into deep depressions, to avoid epileptic seizures, and to reduce intractable pain. Several patients who suffer from psychosis and for whom chemotherapy has failed, have already been treated with CCS to help them on the path to normal behavior. The technique has been used with neurotics, schizophrenics, and others who have experienced the feelings of extreme anger often associated with psychosis or violent behavior (Heath, 1977). Other cerebellar stimulators have been implanted to minimize the spasticity and athetosis associated with cerebral palsy (Cooper et al., 1976). In the patients treated for cerebral palsy, significant improvements were noted in both cognition and memory (Cooper & Goldman, 1987). In addition, it has been suggested that other forms of brain stimulation (CSAT - chronic stimulation of anterior nucleus of thalamus) might profitably be employed to reduce other syndromes such as Alzheimer's disease, autism, Huntington's chorea (Cooper & Upton, 1985), and obsessive- compulsive behavior (Cooper et al., 1985).

Partly related to cortical stimulation is the experimental work on electrical muscle stimulation which permits electrical impulses to be fed directly to inactive muscles paralyzed by injured spinal cords (Petrofsky, Phillips, & Heaton, 1984; Petrofsky, Phillips & Stafford, 1984; Phillips & Petrofsky, 1984). (A 1985 TV-movie called "First Steps", starring Judd Hirsch and Amy Steel popularized the research of bioengineer Dr. Jerrold Petrofsky of Wright State University, Dayton, Ohio, and his attempt to make student Nan Davis walk again.)

Brain pacemakers have been used successfully for the treatment of Parkinson's disease. Patients with Parkinson's exhibit tremors in many areas of their body, associated with overactive cells deep inside the thalamus of brain. Recently, one of the most highly effective treatments to reduce these tremors is to have a deep brain implant, where patients could have an electrode implanted in the thalamus that constantly stimulates these overactive cells and inhibits them from firing. Instead of destroying cell tissue, these stimulators allow patients to function normally by reducing or eliminating tremors caused by these abnormally overactive cells.

Deep brain stimulation has been recommended as a viable treatment for Parkinson's disease with nearly 80% of patients reducing tremors, yielding marked benefits without adverse side effects common with medication (Kumar, R., Lozano, A.M., Kim, Y.J., Hutchison, W.D., Sime, E., Halket, E., Lang, A.E., 1998; Arle, J.E. & Alterman, R.L., 1999).

The mere existence today of simple versions of such devices as brain and muscle stimulators to help alleviate specific medical conditions points the way to a potentially bright future for the more complex models of tomorrow.

3. BIOCYBERNETIC COMMUNICATION

In the third area of development, biocybernetic communication, experimental work is underway in an attempt to interpret brain wave patterns to link them to specific thoughts. In early work at Stanford University, researchers were able to have a subject that was connected to a computer screen move a white dot around simply by thinking about it (Pinneo et al., 1975). One obvious goal of biocybernetic communication would be to use thought to control a wide variety of appliances. For example, it is now possible to harness thought to facilitate a broad assortment of human activities from controlling video game actions to controlling computers.

On your head: IBVA

IBVA Technologies (http://www.ibva.com) has developed a method for harnessing signals from the brain and using it to control computer technology. The Interactive Brainwave Visual Analyzer (IBVA) is an interactive biofeedback control of brainwave functions. The IBVA picks up electrical brain activity through a scalp monitor and can translate brainwave signals into any electronic signal that can control mouse movements, game joysticks, buttons, and any other electronic device. Many recording artists have used the IBVA system to control midi synthesizers and digital audio mixers in order to create music with their minds. Others have used The IBVA system to control CD players in their homes. The IBVA might be the next step towards the symbionic mind (DeVito, 1999).

In your head: Dr. Roy Bakay

Dr. Roy Bakay and Dr. Phillip Kennedy of Emory University have gone a step further. In the fall of 1998, Bakay successfully implanted a chip inside the head of a paralyzed patient. The patient, J.R., had suffered a stroke and was completely paralyzed, unable to speak or move though he retained his cognitive abilities. Bakay hypothesized that if it could be determined which area of his brain controlled the firing of his muscles, then he could intercept this signal and train J.R. to use his own brain to control a computer. Bakay was successful not once, but twice. By using a high-resolution brain scan (MRI), Bakay determined a highly active area of J.R.'s brain in the motor cortex (Wiechman, 1998; Herberman, 1999). Bakay implanted two small cones that transformed chemical neural signals into radio transmissions, which was picked up by the computer. Each cone controlled one axis of movement in two dimensions (up-down, and right-left). The radio signal was converted into an electrical signal in the computer, which controlled the movement of the mouse. J.R., without the ability to move or speak, could control a computer mouse and type on an on-screen keyboard to communicate (Wiechman, 1998; Herberman, 1999). J.R. could communicate effectively, albeit slowly with individuals, a feat not previously thought possible. Bakay's contribution to technologies advancing the symbionic mind demonstrates direct computer control from patterns of thought. J.R. demonstrates a telepathic (or more specifically a telekinetic) ability to control a computer and use it to communicate with others. Brain control of computers is no longer limited to the realm of science fiction.

In your body: Dr. Kevin Warwick

Kevin Warwick from the Department of Cybernetics at the University of Reading in England was placed in the history books as the world's first cyborg. In August of 1998, Professor Warwick underwent surgery to implant a small transponder (23mm long and 3mm in diameter) encased in glass inserted under the skin of his arm.

This implant emitted radio frequencies that communicated with external devices that allowed Warwick to interact with machines, even becoming part machine himself. This silicon chip would communicate with various computer receivers, identifying Warwick without his intervention. When he entered his house, he would be personally greeted, room lights would turn on in his presence and off in his absence and other individualized effects (Cuen, 1998; McClimans, 1998; Witt, 1999). Warwick became a cyborg, part man and part machine allowing for automatic, ubiquitous communication between the two.

Although a remarkable technological achievement with incredible societal implications, Warwick's implant does not directly relate to the development of a symbionic mind. The implant that he received was merely an electronic marker or tag and did not demonstrate any intrinsically intelligent behavior. His chip implant is only semantically different from carrying a smart ID card outside the body. Likewise, Warwick could not assert control over this chip, nor did he have any direct impact on its operation.

Any device which now exists would be intrinsically more useful were it under the direct control of the human brain (c.f. Birch, 1989). This is the aim of Erich Sutter's Brain Response Interface (BRI) unit being developed at the Smith-Kettlewell Institute of Visual Sciences in San Francisco. The prototype device uses four electrodes implanted in a patient's brain to determine which computer command the patient wants executed. The current configuration makes available some 2,048 user-programmable control options (Rosenfeld, 1989). Success in this endeavor, of course, will depend on deciphering the nerve code of mental activity.

Although WearCam designer Steve Mann (originally at the Wearable Computing Project, MIT Media Laboratory (http://www.media.mit.edu/wearables/) and now at the University of Toronto Humanistic Intelligence Lab) developed methods of exporting his field of vision, this does not strictly constitute a symbionic mind. The extension of this work, however, from wearable computing to its control by the human cortex would constitute a definite step towards the creation of the symbionic mind. Already, Wearable Computing Project members at the MIT Media Laboratory are investigating the transmission of computer signals through the human body. The modification of these by the human brain would constitute a further step towards the symbionic mind.

It is the extension of these kinds of biocybernetic research which may result in mental communication between individuals and machines, and even between individuals, in a manner similar to telepathy but based on proven scientific principles and sophisticated technology.

4. NEUROMETRICS

In the associated area of neurometrics, the study of evoked- response potentials (EPs) in the cortex has produced interesting results. These are achieved by measuring minute voltage changes that are produced in response to a specific stimulus like a light, a bell, or a shock, but which are of such small amplitude as to not show up on a conventional electroencephalogram (EEG). An averaging computer sums the responses over time to make them stand out against background noise. Since the background noise is random, it tends to be canceled out. Through the use of this technique, it has now been established that the long latency response known as the P300 wave (positive potential, 300 millisecond latency) is usually associated with decision-making activity (Lerner, 1984). Though the wave appears after each decision, it is often delayed when a wrong decision is made. Theoretically then, it should be possible to construct a device to warn us when we have made a bad decision, to alert us when we are not paying attention (a boon to air traffic controllers) or to monitor general states of awareness. It is also possible using EPs to distinguish motor responses from cognitive processes, and decision-making processes from action components (Taylor, 1979). As its objectivity patient cooperation is not needed) and non- invasiveness come to be appreciated, more and more clinical applications of EPs are beginning to appear (Ziporyn, 1981a; 1981b; 1981c), and it is likely that the number of non-clinical applications will also rise.

5. ARTIFICIAL INTELLIGENCE

The fifth area is that of artificial intelligence which includes the study of pattern recognition, problem solving, and speech comprehension with a view to reproducing these abilities in computers (Crevier, 1993). During the last decade, there has been a renewed interest in the study of neural nets to model cortical functions on a computer (Pagels, 1988). All of these developments will find applications in the creation of the symbionic mind.

6. BIOTECHNOLOGY

Increasing importance is the work in the sixth area, biotechnology, sometimes referred to as genetic engineering. In small laboratories around the world, scientists are at work attempting to use genetic engineering principles to construct tiny biological microprocessors of protein or "biochips" (Futuristic computer biochips..., 1981; McAuliffe, 1981, Posa, 1981; Whatever happened to molecular electronics?, 1981; Milch, n.d., Schick et al., 1988). The advantage is that by using the techniques of recombinant DNA, very small devices (VSDs) can be assembled with great precision. As unbelievable as it sounds, such biochips may even be designed to assemble themselves, perhaps even in three-dimensional forms in the microgravity of outer space (McAlear, n.d.) If such biochips can be successfully constructed, it is likely they will have higher density and higher speed, and will consume less power than conventional chips (Drexler, 1986). This in itself will be no mean achievement because of the continuing reduction in circuit size below that of a living cell. Successful though the silicon chip is, new circuits the size of molecules and smaller are already being developed which could significantly damage the silicon chip industry and ultimately lead to the creation of a molecular computer. Biochips would have a greater probability of successful implantation in the cortex due to their higher degree of biocompatibility. One company in America has received a grant from the National Science Foundation for a feasibility study of the creation of a direct interface between the central nervous system and an integrated circuit. Their initial plan called for increasing the number of effective electrodes from an 8 x 8 platinum array currently used in clinical trials to an array with 100,000 electrodes. The development of such technology will depend heavily on the use of an implanted integrated circuit and state-of-the-art microfabrication or nanotechnological techniques. The actual device is expected to consist of electrodes connected to an interface of cultured embryonic nerve cells which can grow three-dimensionally and attach themselves to mature nerve cells in the brain (EMV Associates, 1981; The next generation..., 1981). Ultimately, the provision of the appropriate set of genes could enable such a chip to repair itself, DNA codes could be used to program it, and enzymes used to control it (Biotech..., 1981; Drexler, 1986). Already under development as a first step is a device called an "optrode" consisting of a polymer waveguide with a photovoltaic tip capable of photon-electron conversion. Research has been undertaken to study the feasibility of using such a tiny, photoconducting microelectrode to record the firing of a single neuron, or perhaps even to cause it to fire (McAlear, & Wehrung, n.d.). Beyond recording the firing of a single neuron, the firing patterns of whole neuron cultures can now be monitored (Gross et al., 1985; Droge et al., 1986).

7. VIRTUAL REALITY

The seventh area of virtual reality has received a lot of attention in the last decade. The goal of virtual reality is to create alternate realities by manipulating sensory inputs to trick the brain into believing it is somewhere else. However, each of these sensory manipulations, though designed to contribute to the virtual reality experience, teaches us about how to manage sensory input to the cortex.

The Birth of Symbionics

These seven areas have much in common. For the most part, they deal with the brain directly, with perceptual and thought processes individually, and with intellectual activity primarily. Like other media, they are steadily converging (Brand, 1988). Once a merger is effected culminating in a routine way of interfacing with the brain either directly using implanted (or grown in place) electrodes, or indirectly by picking up brain waves with external sensors (biocybernetic communication and neurometrics), the symbionic mind will have been born.

The Symbionic Mind may be defined as any apparatus consisting of some useful device, interfaced with the human brain, capable of intelligent action. The most difficult task in its creation will be the design and construction of the interface required to link these devices to the human cortex. Such a complex interface will no doubt represent the major component of the symbionic mind, and the creation of a wide range of standard and optional accessories to attach to it will probably prove to be a comparatively easy task. Such auxiliary brain prostheses or symbionic minds are beginning to be used for appliance control (IBVA) computation, monitoring of particular body functions, problem-solving, data retrieval, general intelligence amplification, and inter- and intra-individual communication. The ultimate revolutionary advance may even be the direct, electronic transmission of human thought!

Symbionic Functions

The most obvious use for a symbionic mind would be to improve human memory. It is easy to see how people with failing memories might benefit from supplementary aids - in this case tiny mind prostheses or "add-on" brains with extra memory storage and better retrieval. Like a memory crutch for the brain, the symbionic mind could be invaluable for patients with Alzheimer's disease. The benefits to education would be enormous (Cartwright, 1982; 1983b) not only for average students but for gifted students as well (Cartwright, 1983c).

Symbionic minds will do more than just improve memory, but as yet one can only speculate as to their full range of uses. Because the symbionic mind will be able to interpret our thoughts, our very wishes will become its commands. Thus it will be able to take dictation directly from our thoughts, improve them through editing, and like the voice-processors of today, rearrange whole paragraphs, perform spelling checks, and supervise the typing of final documents. To some degree, the human brain may be limited by its small number of input senses. But a symbionic mind connected to the brain to amplify its abilities, improve its skills, and complement its intelligence, could be used to handle additional sensory inputs, and to make low level decisions about them, discarding irrelevant data, and passing on more important information to the brain itself. In the future, it may be possible to build into the symbionic mind totally artificial senses and connect them directly to the brain. These artificial senses would simulate most of our existing senses but would bypass currently available receptor organs, in a manner similar to way in which Flanagan' s Neurophone is reported to input sound directly to the brain, bypassing the auditory nerve (Begich, 1997). Some of these might include components of our existing senses; others will be totally new and the line distinguishing one sense from another may become increasingly blurred.

Exactly what these new senses will be and the uses to which we shall put them must remain, for the moment, in the realm of speculation. However, examples might include senses to detect currently invisible hazards like harmful levels of radiation or pollution in our immediate environment, or to relay television transmissions or Internet information directly to our brains without the aid of conventional monitors. TV sets and video monitors are merely converters: they convert signals we are unable to receive in our natural state into visual signals on the screen which can be input through our eyes. From the eyes, the signals are converted to electrochemical impulses and sent to the visual cortex for analysis. Imagine a small device which could receive signals, but instead of displaying them on a video screen, could channel them directly to the human cortex. The sensation of "seeing" the pictures would still exist but one's eyes would be freed for watching other things. Such devices would not be limited to television and computers but might include radio and telephone reception as well. In all these instances, the normal sensory inputs of eyes and ears would be bypassed.

Already preliminary work in this direction was undertaken some years ago at the University of Florida to find ways of implanting up to 100,000 miniature photovoltaic cells to stimulate previously unused parts of the retina in cases of retinal blindness. The Dobelle Institute (http://www.dobelle.com) is currently developing a visual device that would use neuro-stimulation to create artificial vision for the blind. Early developments of the technology are crude, only allowing differentiation between light and darkness, however, the implications of this development are far reaching. It may soon be possible for science to bypass the eyes entirely and feed visual information (from a camera mounted on eyeglasses) directly to the cortex (Dobelle Group, 1999). Though the immediate medical goal is to produce a more effective visual prosthesis, the perfection of such a technology has much wider implications.

In the auditory domain, patients at the Los Angeles Ear Research Institute have been fitted with electronic ear stimulators to stimulate auditory nerves in an attempt to improve hearing. Called cochlear implants, the technology has been proven to help the profoundly deaf hear and many who have had the implants have reported that they are glad they did and would not be without it.

The symbionic brain will provide a sophisticated interface between ourselves and a wide variety of household gadgets. The symbionic mind will provide a "thought switch" to enable us to control appliances merely by thinking about them, like the commercial products demonstrated by IBVA.

The symbionic brain will turn lights on and off for us, activate television devices and switch channels (feeding the signal directly to the brain), answer telephone calls and initiate them, and keep household inventories. It will guard us from a number of dangers and protect us in a wide variety of situations. At a party it will monitor our blood alcohol level and warn us when we have had too much to drink. It will keep an eye on other bodily functions including digestion and blood sugar levels, and warn us of impending illness, undue stress, or possible heart attacks. It will guard us while we sleep, listening for prowlers, and sensing the air for smoke. It will attend to all household functions and perhaps ultimately will direct the activities of less intelligent household robots which are sure to come into existence. It will share with us its vast memory store and its ability to recall information virtually instantly - information we thought we had forgotten. It will put us in touch automatically with huge data banks containing information it does not possess itself. It will do math calculations, household budgets, business accounts, and even make monthly payments for us automatically. It will update its own information daily by scanning a number of information sources, perhaps listening to its own information channel, perhaps digesting local newspapers, sifting for information which it feels it should bring to our attention, helping us make sense of the world around us. It will provide a whole new dimension of living to quadriplegics allowing them to perform many of the routine daily tasks essential to life, and restoring to them some measure of control over their lives. It will change the entire realm of communications as we know it today. Merely thinking of someone you wish to talk with by telephone will initiate a search by the symbionic mind to locate that person anywhere in the world and establish direct contact. Though physical telephones will be avoided, the two symbionic minds will be in direct communication over the cellular telephone network, and thoughts will flow between beings in seemingly telepathic fashion; indeed this may be the closest we will ever come to true telepathy. How ironic that even if telepathy does not exist, we may nevertheless be able to simulate it anyway.

The Future of Symbionics

Feedback from Virtual Reality (VR) to control the body

It can be readily seen how the bombardment of the body's senses by VR generated information can have a direct effect on the systems of the body. Heart rate may increase, respiration quicken, and palms perspire. Improved VR experiences may be tailored to effect specific changes in other bodily senses like smell or balance.

VR input could be used to bypass the usual human senses and be fed directly to the symbionic mind for direct input to the brain. Visual, tactile, auditory, olfactory, and gustatory stimuli could be transmitted directly to the cortex. An example might be infrared information transmitted directly to the symbionic brain and overlayed on the visual system giving the user the semblance of infrared vision.

Feedback from the Body to control VR

Similarly, but in a reverse direction, it should be possible to use feedback from the cortex to control the inputs to VR to enable the technology to tailor or individualize the perceptual experience. For example, a person in a state of fright because of some VR-related phenomenon would experience particular Galvanic Skin Responses (GSR), EEG-readings, increased heart rate, adrenaline levels, and orienting responses which can be detected by the VR apparatus to re-render the environment to help stabilize the user. In this way, VR could be used adaptively to protect the user from harm.

Transmission Methods

Symbionic minds using wireless full duplex (two-way) transmission could be used to receive broadcast or narrowcast VR. Broadcast VR would transmit a single experience to multiple recipients; narrowcast VR would transmit multiple experiences to a single user.

The provision of wireless full duplex symbionic technology will also facilitate the addressing of every individual. Perhaps each with their own Internet Protocol (IP) address for electronic identification, like computers on the Internet of today. In the past, people telephoned a location and asked if a person was there. Today with digital cellular telephony we phone a person and ask where they are. This new technology facilitated a paradigmatic shift from using the telephone to dial a person instead of a place. Currently IP addresses denote physical locations. In the future, they will represent personal symbionic contacts with specific individuals.

Resting Power Potential

With every symbionic mind connected to every other, the possibility exists of harnessing extra brainpower during sleep to process information. An analogue now exists with the SETI@Home project from UC Berkeley where millions of unused home computers work nightly to process chunks of astronomical data.

In conclusion…

The symbionic mind will not be a truly separate brain but will be an extension of us, of our very being. It will not seem to be foreign to us in any way, nor will it pose to us any kind of threat by trying to take us over any more than would our own brain. The symbionic mind will be as much a part of us as a hand or an eye, and it will seem to us simply our own brain doing the thinking. It will be transparent to us. We will not be aware of any separate entity, nor of any other change except an increased ability to perform those intellectual asks we have always performed, and a new capability to accomplish those which were previously impossible.

The new symbionic mind will act purposefully and willfully, but always on our behalf and at our direction. It will be our constant companion and friend, conscience and alter-ego. The science of symbionics culminating in the development of the symbionic mind may well mark the next significant step in our evolution to a higher plane of existence, and the dawn of a new era.

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The field of artificial intelligence is pushing the boundaries of what science considers intelligence and can have a great impact on the development of the symbionic mind. Scientists such as Avery Brooks of the MIT Artificial Intelligence Laboratory have been pioneers in the development of a more holistic, global AI. In classical AI much research has been devoted to building complex creatures in very specific, non-realistic worlds. In previous research, expert systems were created that could not function outside of their own domains of application. Classical AI had researched itself into a corner, no longer able to apply their "intelligent" creations to the real world. Brooks and other researchers realized the incredible limitation that classical AI has placed upon itself. They brought forth a new, alternative view of Artificial Intelligence. This Nouvelle AI is based on the grounding hypothesis which states: "...to build a system that is intelligent, it is necessary to have its representations grounded in the real world " (Brooks, 1990).

In Nouvelle AI, simple creatures are constructed, using a real world model. Instead of attempting to reduce intelligence to simple computer functions, Nouvelle AI assumes that intelligence is a combination of many behaviors, not a simple list of computer functions. If a robot can perform simple, realistic, applicable behaviors, they would be emulating simple intelligence that exists in the real world. This more holistic view of Artificial Intelligence has facilitated groundbreaking research (Brooks, 1990). More and more Artificial Intelligent systems and computer chips are using neural nets and fuzzy logic in order to control complex processes (Gould, 1995). Fuzzy logic systems are able to approach the world in a much more holistic manner, with the ability to deal with real-world problems and ambiguities, without reducing them down to simple, non-realistic computer functions. By definition, the symbionic mind must be capable of intelligent action, research in AI must coordinate efforts with cognitive scientists in order to interface with the human mind.

2. WEARABLES

The portability of computers has achieved incredible advances in technology in the last 10 years. Computers are becoming smaller, more powerful and easier to use. Laptop computers are often difficult to buy due to high demand. Airports, airplanes, railway terminals, trains and other modes of transportation are increasingly meeting user demands for portable-friendly environments. Most airplanes provide in-flight internet access, even across the ocean. However, this was still not enough for the users. Users demanded smaller machines, increased portability and easier individualization. The fantastic success of the 3Com Palm computer created a new market niche for Portable Digital Assistants (PDAs). Users could now fit small computers in their shirt pockets, access the net from the middle of Manhattan on a street corner and beam important information from PDA to PDA through wireless infrared technology. However, this was still not enough for users. They demanded more. They demanded wearable computing.

A) WEARABLE COMPUTING The first International Symposium on Wearable Computers was held at MIT in Boston MA in 1997 with record attendance.

The same thing could be done with x-ray vision for engineers to discover structural problems, enhanced auditory input for musicians and sound engineers, improved gustatory input for wine tasters (to detect otherwise untasteable poisons), improved olfactory detection for detecting gas leaks, enhancing the appreciation of floral display, bomb detection, people detection and recognition, food appreciation, kinesthetic augmentation by the elimination of body suits, brain orgasms etc.