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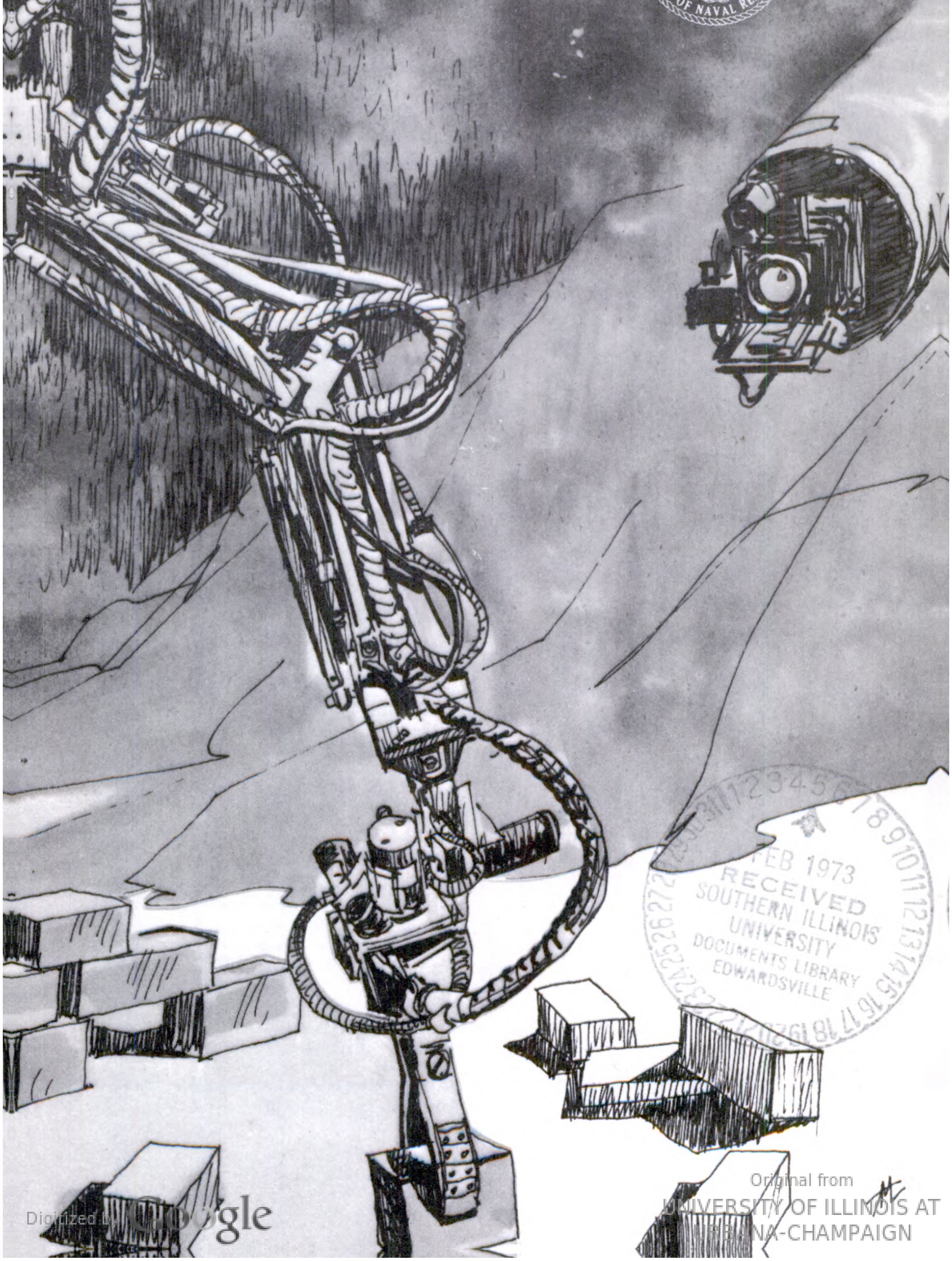

PROFILES IN SCIENCE

Dr. Dora Strother

Dora Dougherty Strother, as Chief of the Human Factors Group at Bell Helicopter Company, Fort Worth, Texas designs helicopter cockpits and display-control systems to optimize human performance and personnel safety.

Dr. Strother is a licensed instructor pilot and certified psychologist. Her research contributions for improvements to helicopter cockpit instrumentation and displays extends from 1953, and is documented in numerous reports and publications. For the Office of Naval Research, her work contracts with Bell Helicopter Company began under the Army-Navy Instrumentation Program (ANIP) and continued under the Joint Army-Navy Aircraft Instrumentation Research (JANAIR) program.

Until recently, Dr. Strother held two feminine world flight records for rotorcraft, altitude and distance. During World War II she was an Army Air Corps pilot with the Womans Airforce Pilot Program, and is now a LT. COL. with the U.S. Air Force Reserve. President Johnson appointed Dr. Strother to the Woman's Advisory Committee on Aviation of the Federal Aviation Agency.

Dr. Strother is a member of the American Psychological Association and the American Institute of Aeronautics and Astronautics.

How to Teach a Robot

Marvin Minsky*
Massachusetts Institute of Technology

It is our goal at the Artificial Intelligence Laboratory at the Massachusetts Institute of Technology to conduct research on techniques to endow robot-like devices with human learning, viewing and manipulative capabilities.

Established under an ONR (Office of Naval Research) contract with ARPA (Advanced Research Projects Agency) funding, our laboratory is learning how to design robots that will be able to survey their environment and move about in it under control by natural English instructions. Such robots would not only see (the eye is a television camera) and hear, but would also have a sense of touch.

These devices, which would be remotely controlled by computer, are expected to be able to supplant or supplement man in performing tasks in hostile, or stressful, or very remote environments, such as deep sea exploration (see Figures 1 and 2).

The approach at our laboratory is different from that taken at other research centers. We see the difference as fundamentally in the approach to handling apparent diversity of kinds of knowledge. The common approach at other centers is to seek ways to render it more uniform so that very general or logically clear methods can be used. Our approach is to accept diversity of knowledge as real and inevitable, and find ways to manage diversity rather than eliminate it. An exciting aspect of our novel approach is that it promises at last to break up the stereotype of the computer's slavish dullness, or the superspeed moron character.

A good example of a degree of common sense is supplied by the interactions of the programs in the "Blocks World" designed by Terry Winograd (1). Winograd's system is a large intricate system. It is called the Blocks World because the robot interacts within a simulated world composed essentially of blocks of various colors, shapes and sizes. The Blocks World is used to serve as a subject domain for the development of a language understanding system. This system is radically more ambitious than earlier attempts to deal with natural language in several respects. It is as much or more concerned with the problem of representing the meanings in a discourse than with the grammatical structure. Winograd asserts that meanings and syntactic structures are so intimately related that it is not practical to try to draw a definite boundary

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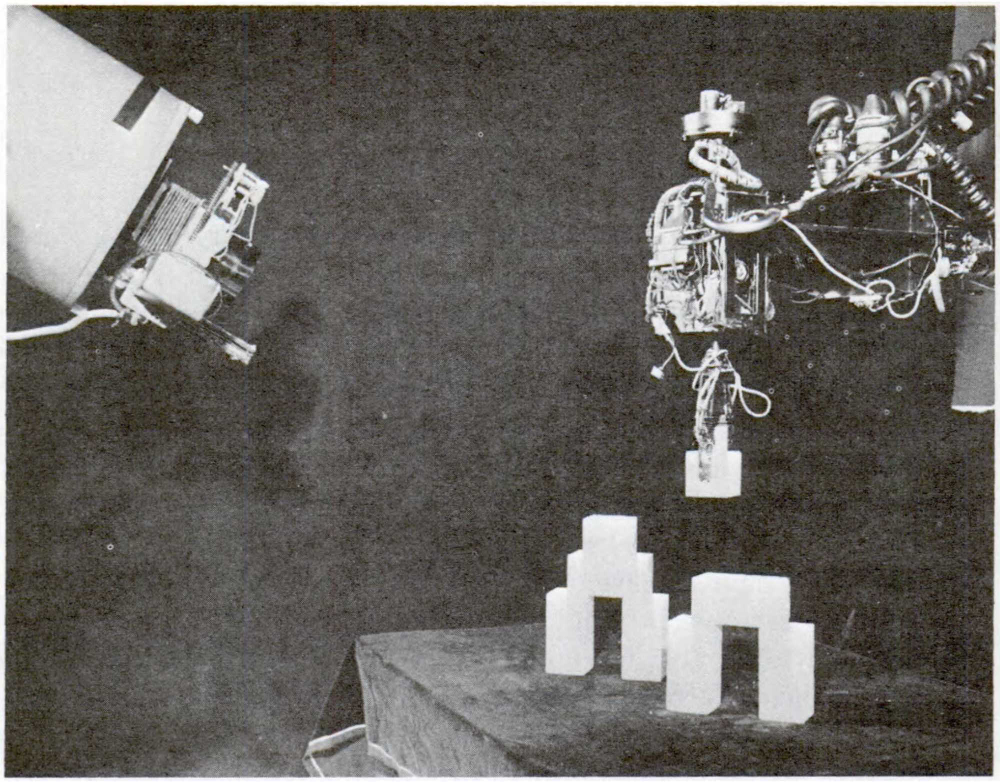

Figure 1 — The robot being developed at MIT will not only see (the eye is a television camera, upper left) and hear, but would also have a sense of touch.

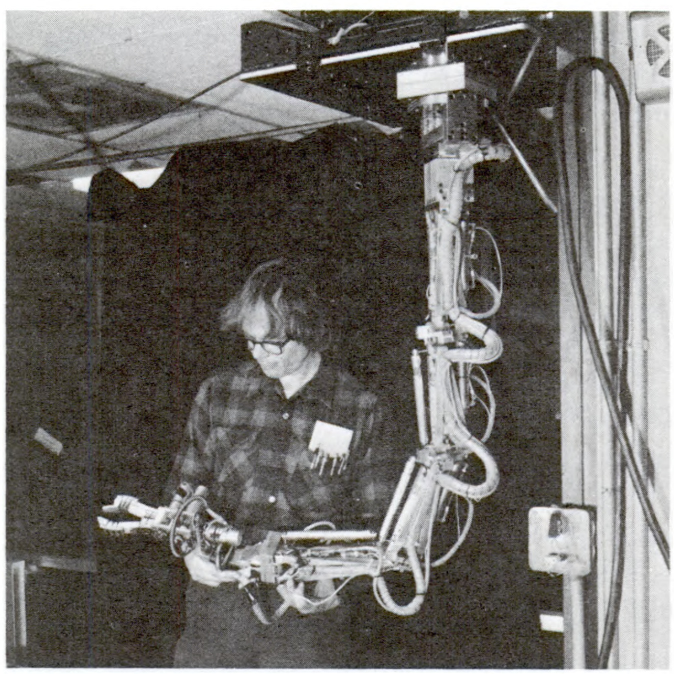

Figure 2 — The robot which will be remotely controlled by computer will be able to supplement man in certain stressful environments

between the procedures that are to be used to draw logical inferences about the meanings carried out in the discourse.

The type of discourse currently in use is illustrated by the following sample carried out in real time with the robot's response displayed on a cathode ray tube (CRT) screen. Figures are included to show the state of the scene at various stages. The natural English discourse is the result of intensive study by Professor Winograd.

1. pick up a big red block.

--------OK.

> The system answers "OK" when it carries out a command. In order to pick up the red block, it had to clear it off by finding a space for the green one and moving the green one away.

2. grasp the pyramid.

--------I DON'T UNDERSTAND WHICH PYRAMID YOU MEAN.

> There are three pyramids in the scene, so the program does nothing.

3. find a block which is taller than the one you are holding and put it into the box.

> The system has to figure out what is meant by "one" and "it," as well as using deduction to decide which block it is holding.

--------BY "It," I ASSUME YOU MEAN THE BLOCK WHICH IS TALLER THAN THE ONE I AM HOLDING.

> Printed out to keep us informed.

--------OK.

> The hand has to set down the red block to pick up the taller blue one. Figure 3 shows the result of the system's manipulations so far.

4. will you please stack up both of the red blocks and either a green cube or a pyramid?

--------OK.

> Logical connectives such as "and" "or" "either" etc. are handled in both the grammar and semantics. A command is executed even if it looks like a question. The command is carried out by the following series of steps: It puts a green cube on the large red block (note that it chooses the green cube with nothing on it), then removes the small pyramid from the little red cube, so that it can use that cube to complete the stack as specified, resulting in the situation of Figure 4.

5. which cube is sitting on the table?

--------THE LARGE GREEN ONE WHICH SUPPORTS THE RED PYRAMID.

> Ordinarily the system would be satisfied with calling this "a big green cube," but since we asked "which cube" it has to be

more specific in naming it. The use of substitute nouns (such as "one") and pronouns.

In answers the computer makes the discourse more natural.

6. Is there a large block behind a pyramid?

--------YES, THREE OF THEM: A LARGE RED ONE, A LARGE GREEN CUBE AND THE BLUE ONE.

7. put a small one onto the green cube which supports a pyramid.

"A small one" must contrast with the earlier phrase "a large block," so this means "a small block."

--------OK.

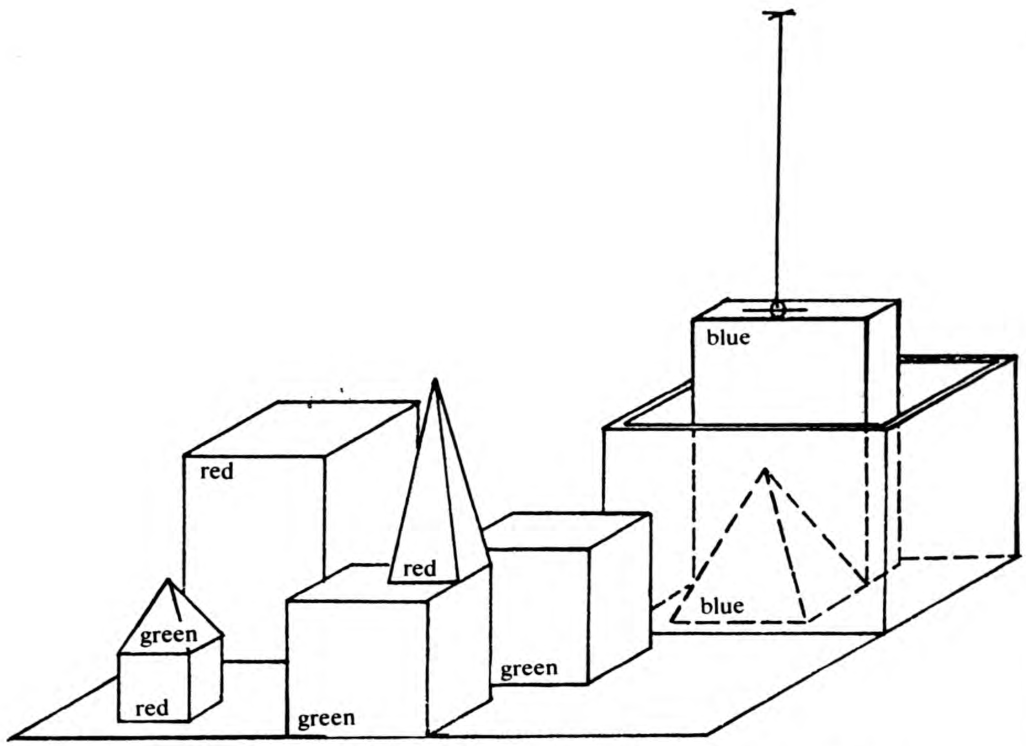

Figure 3 – This shows the robot about to pick up the taller blue block

8. put the littlest pyramid on top of it.

Words like "littlest" are not in the dictionary but are interpreted from the root forms like "little."

--------OK.

DOES A STEEPLE.....

I DON'T KNOW THE WORD "STEEPLE."

The system interrupts immediately when it sees a word it can't figure out.

a "steeple" is a stack which contains two green cubes and a pyramid.

The quote marks indicate that we are defining a new word.

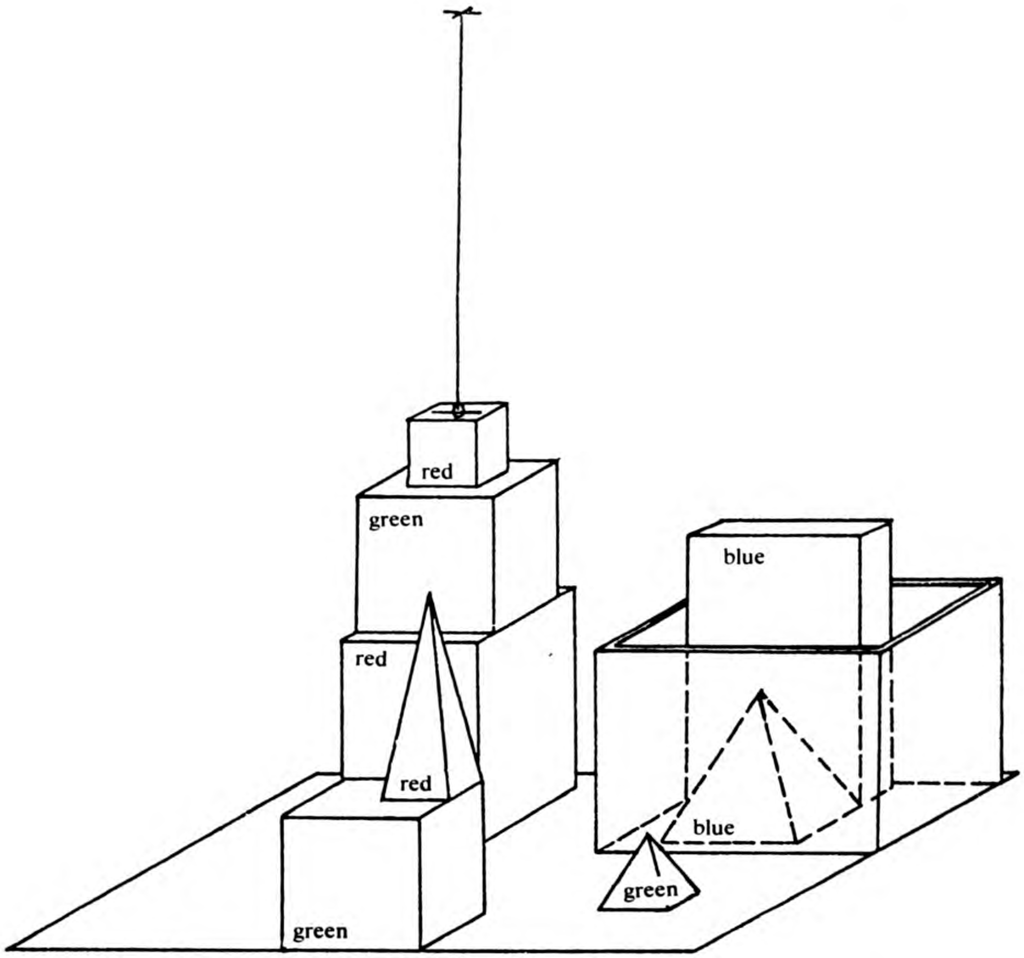

Figure 4 — This situation shows the robot carry out a command which necessitates several steps

--------I UNDERSTAND.

9. are there any steeples now?

--------NO.

The new definition is used as a description to recognize steeples.

10. build one.

--------OK.

The description given in the definition is enough to deduce a plan for building new objects as well as recognizing them. The word "one" means "a steeple," and the plan is carried out. First, one of the large green cubes is cleared off by removing the red cube and two pyramids. Then the two green cubes and the tall red pyramid are stacked up to fit the description.

11. Thank you

--------YOU ARE WELCOME!

Idioms can be defined without modifying the grammar.

The syntactic and semantic systems generate construction goals, like "build a steeple." The definition of the goal given by the human operator ("a steeple is a stack which contains two cubes and a pyramid") is converted into a plan—a step-by-step specification of subgoals—that is interpreted as a program for building a steeple: find a cube; put another cube on it, put a pyramid on that. Now when a first cube is found, its top might be cluttered with other objects. We do not want the robot, like the assembly-line machine in Charlie Chaplin's movie *Modern Times*, to smash the second cube down. But we do not want to write into our plan "find a first cube and remove the things on it" because (1) it is so obvious to say it and (2) it only sweeps the problem under the rug: the program will have to find a clear surface somewhere to put down the objects it takes off the first cube.

Winograd's system faces the problem once and for all. An almost autonomous network of statements and procedures "know" that to put one thing on another, there must be a place where it will fit. If there is no such place, one must make one or fail. To "make a place" one must move something else where *it* will fit. But one cannot put something on itself, even if there is room, because it will not be where it was at the future moment of setting it down after moving it. Instead of writing this sort of thing into each particular application program, we create once and for all a "microworld" of knowledge about how things are supported, how supports change when things are moved, and so forth. This knowledge is invoked by the occurrence of patterns either in the outer world, or in goal-statements, whenever they occur, and the same common-sense processes intervene and take over the actions until their invoking patterns disappear. For example: there is in the micro-world a statement whose effect is

> "If A is supported by B, and A is moved, then erase from the current description of the situation any statement of the form 'B supports A'."

Notice the indirect character of this. It is a statement not about the physics of support but about when to forget statements concerning support. (When you paint an object, and then move it, analogous statements about the colors should *not* disappear.) One could conceivably do without this advice at the cost of recomputing, after each change in the world, all the relations between subsets of objects. This is impractical and is a common cause of examples in which a system works on "toy" problems and collapses on real ones. Or one could do without this advice, at the cost of recomputing, after each change in the world, all the logical consequencies of that change; this leads in a different way to bad performances. One can make heuristic compromises: motions change geometrical relations but not (usually) other attributes of objects. The art, and science eventually, is in finding which points are so immediate that one should know them directly and which can be left to more general but more laborious deductive systems.

Common sense is not magic. If we want our computer to act as though it knows the elementary strategies about physics and geometry, we must give it the knowledge somehow. But we need not do this anew for each program! So our next goal is to learn how to refine the ideas in the Blocks World, and the ideas in pattern-matching invocations that make this knowledge engage relevant situations, so that we can keep this "data" permanently in the system. Then any program written therein will automatically behave sensibly in that sphere of activity.

Some Features of a New Programming Style

1. Use of the Language PLANNER

Programming languages such as ALGOL are designed to make it easy to express the kind of statement that certain classes of users are likely to require: for example, elementary mathematical operations and repetitive loop structures. In programming for Artificial Intelligence we need to express very easily such instructions as

> To achieve Goal A, set up sub-goal B and if this fails, try C or D.

Carl Hewitt (2) has designed a language which is expressive in talking about just this kind of device. Its expressive power is so great that a graduate student was able to write a PLANNER program, to solve high-school geometry problems, in only a few days of work. His program was comparable to one that required several man-years a decade ago. This ability to perform experiments in Artificial Intelligence rapidly and flexibly is a most decisive change in the style and fertility of work, and a limited version of the new language is already being used in several other centers. We are concerned however that a restricted form of the language may become too well established, and will endeavor to make the best possible form generally available.

2. Program-Understanding Programs

This is an area in which rapid growth is very likely. It is closely related to the Natural Language project (Winograd) and PLANNER (Hewitt). The explicit goal is to write programs capable of understanding programs.

We hope over the next year to go further into systems that understand more about processes. There are a number of different aspects of this general goal that arise over and over again in work on Artificial Intelligence and in many branches of computer science.

Learning programs like that of Patrick Winston (3) produce descriptions of structures from a sequence of examples that have been presented. Much of learning involves the acquisition of new processes. We do not believe that there is necessarily a large difference between acquiring descriptions that represent the structures of objects and descriptions that represent the specification of procedures. But if we are to be able to do the later, we must experiment with problem-solving systems that deal directly with the semantics of programs, and such experience is generally lacking.

More generally, in order for a learning program to be versatile, it must be able to analyze procedures that it learns, to adapt them to new situations, to debug them, *etc*. We believe that children who are not able to cope with complicated situations are that way partly because their process-understanding capability is inadequate.

3. Automatic Mechanisms for Fallibile and Contingent Instructions

The image of a classical computer program is that of sequence of actions performed one after the other and expected to succeed. In Artificial Intelligence programming, an action might be an attempt that fails. In this case it is necessary to ensure that when it gives up, the micro-world in which it works is not left cluttered. The PLANNER system contains special mechanisms that enable the system to restore a description to its former state with some relevant data about the failure.

It is slightly ironic that the most popular approaches to Artificial Intelligence programming force knowledge to be stated in a form of logic as assertive propositions such as:

> "The Large Box is Red"

Now, there is no problem in such simple statements about attributes. But other kinds of knowledge are better stated as procedures (or programs) rather than as facts. Even such a simple statement as:

> "If there are no cars coming, cross the road"

is misleading if translated into a logical implication such as:

> For every x, if (x is a car) and (x is not coming) then (crossing is permissable)

It is more naturally transcribed as:

> "Look left, look right, if you have not seen a car, cross."

The distinction between these modes of expression is not merely verbal. A deeper aspect is seen by picturing a logical theorem prover trying to prove by resolution or other logical principles that no car is coming! Deeper yet are the consequences in more complex situations. We believe that even in the size of programs we are now using they make a difference between easy programming and very difficult programming. With more complexity we believe that the difference can become one of possible *versus* impossible.

An example of procedural necessity may be seen in the concept of nearness. Everyone knows what "near" means. If we told you that the car is near the garage and the garage is near the house, then we can be sure that the car is near the house. But we cannot put this transitivity into a formal logical system by a rule like

Rule 1. If (A near B) and (B near C)

for unrestricted application for this rule would yield absurdities like "1 is near 100" because 1 is near 1.001 and 1.002, *etc!*

It is clear what the real problem is. In any particular context, "Near" is used to represent range, and if one uses chains of longer than a few steps, one may get out of the range. To express this, one might add a rule like:

Rule 2: Do not use Rule 1 more than (say) four times unless there is some basis for believing that you are still in the same size range.

This cannot be said in any ordinary "logical system." No system of mathematical logic allows statements inside the logic to talk about the deductive process that uses the logic. This is bad for intelligent systems, because in solving a hard problem one must devote much attention to monitoring and planning the problem-solving activity. We can state Rule 2, or the equivalent, in a PLANNER-like language, quite directly.

This attitude is not shared by most other groups working on Artificial Intelligence, and there is a widespread committment to try to represent ordinary reasoning in terms of a "consistent" mathematical logic system. There is perhaps some analogy with a generally unsuccessful earlier preoccupation with perceptrons and linear-separation clustering algorithms—another kind of attempt to find a uniform way to represent all different kinds of things. On the other hand, there is a great deal to be gained by understanding both sides of such questions.

There is an interesting sidelight on this. Many people interpret Godel's theorem as showing a difference between man and machines. It does not. What it says is that any system which is able to discuss its own procedures, and apply these to itself, has the potentiality of deducing some falsehoods. It is perfectly possible to program computers to be able to discuss their own procedures—Winograd's program comes close to this—and we believe that this is the best path toward intelligent programs. Rule 2 is a simple instance. We do not believe that enough is known

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today to make worthwhile a search for an adequate and "consistent," logically intelligent system (that is, one that is inherently unable to have any self-contradictions). This has never been done even for ordinary mathematical arguments, to say nothing of everyday common sense.

What humans do is much more PLANNER-like. Suppose that one deduces a contradiction in some argument or finds that some plan that was expected to work out does not. One looks backwards and tries to localize the trouble. Then one constructs and remembers a pattern-invoked heuristic rule, to prevent that kind of deduction being made again. "Rule 2" is just such a device. A more technical example is provided by the way real mathematicians deal with "native set theory." They do not reject it as did Bertrand Russell in his attempt to rebuild mathematics without it. Instead they now have rules like: "If your statement resembles Russell's Paradox (because it talks about itself) then be careful; find another way to do it." It is astonishing how successful a few simple warnings like this have been in keeping contradictions out of ordinary mathematics. And we believe that among the most important forms of everyday human knowledge are just such rules that indicate which lines of thinking are unsound. Another example: whenever one finds a theoretical outlook which can explain things "too easily," as do mystical concepts of "unity in everything" or the dialectical elements in Sigmund Freud's Theory (in which many causes can produce opposite effects) one says to himself that "Aha, this method is *too* good." Then one tries to build up protective knowledge structures for preserving what one can (Freud did indeed propose many valuable new ideas about how knowledge is represented and misrepresented) of the new theory.

We believe it is the only promising approach, today, to understanding intelligence. In taking this path, however, we must be very clear about the risks. We must understand that as our programs get better at analyzing their own processes, and incorporate better heuristics for preventing unsound kinds of reasoning from emerging, the possibilities of contradictions become buried more deeply, but are not eliminated. We must not be entirely diverted by good empirical results. We must not give up on trying to get a complete theory. It is certainly not inconceivable that we can some day construct a systematic theory of consistency in a logical area wide enough to cover all important areas of intelligence. Such research will be vital, some day, in protecting our interests, if and when we become able to construct extremely intelligent machines!

4. Mini-Theory Construction as a Technical Goal

We see the problem of Artificial Intelligence as more than just programming existing knowledge. It also involves the acquisition and classification of new substantive knowledge about such areas as intentions, excuses, and goal structures. A curious feature is that, in the past, such inquiries that have been conducted have been the domain not of "scientists" but of analytical philosophers and literary critics! Because their analyses were limited by the lack of computational models, we are able to go further. These advances depend on increasing sophistication in areas of thinking far removed from the usual computer science courses.

For example, Eugene Charniak in our laboratory is working on making programs understand narrative. This work has reached the level of an experimental program capable of answering some questions like the one in the following example. Below is a story taken from a children's reader which is "read" to the computer. Next are our question, the computer's answer and comments on the process. In its present form the program interacts with a special format; we have translated this into English for simplicity of reading, and much more needs to be done before ordinary tests could be "understood" this well.

Story

Jack and Janet are in the house. Jack is holding a box of pencils and a box of paints.

"Janet, see the paints and pencils that Daddy got for us," Jack said.

Janet went to look at them.

"Are the paints for me?" she asked.

"No, the paints are mine," said Jack. "The pencils are for you, Janet."

Janet said to herself, "I want the paints."

Jack began to paint a picture of a red airplane. Janet went to look at it.

"Those paints make your airplane look funny," she said "You could make a good picture of a red airplane with these pencils."

Question: Why did Janet say that the paints were bad?

Answer: She wants the paints.

Comments: The program must interpret "funny" as "bad" in this context (this is not done for it in the input format). Even then Janet really said the picture was bad, and it is necessary to transfer this to the paints. Then the program must know that if you want something another person has, you might make nasty comments about it in order to get it. If we had asked, "is the picture funny," the response would have been (in essence) "No, she said so but she had an ulterior motive." To do this the program needs a lot of information about wanting, trading, giving, owning. Statements can not be taken at face value—translated into simple logical statements. They must be treated as evidence for the program to use to build a model of what really might be happening.

So far as language is concerned, there are a number of new areas that demand investigation such as the problems in handling other aspects of ordinary grammer and the need for additional new primitives. These problems are inseparable from those that arise from adding a wider range of meanings to the entire semantic system. What happens when we try to extend Winograd's system beyond those problems that it now can handle with respect to the Blocks World? There are alternative concepts of how to proceed, and let us consider two extremes:

One approach is to add to the Blocks World incrementally. It is easy to add new kinds of objects, and properties for them, to the syntactic-semantic-problem solving complex.

It is somewhat harder to add new predicates about spatial relations; for example, "Next to" might be important in some problems. But such an increment means that one must also add new procedures for taking account of such new elements, be they mentioned explicitly in a main goal derived from a natural language command, or generated internally in a description invoked by a theorem already present. The new procedures represent ways to solve problems and understand situations, but they cannot be used efficiently unless recommendations are added to the theorems of the older knowledge base so that the syntactic and semantic systems can handle the nuances associated with the wider spectrum of meanings that the system is now required to deal with.

Presumably, as this kind of incremental extension is made, some changes will be easy. Whenever the system does something that "it should know better than to do" the programmer can intervene and attempt to adjoin new "advice" as a new theorem, recommendation, or entry in the dictionary, or as a fragment of PROGRAMMER or PLANNER program. Sometimes this will be difficult because, instead of a small addition or change, the system will want a new kind of data-structure, or a new heuristic strategy for achieving a new kind of goal.

For example, Winograd's Blocks World does not have a variety of "uses" for the mechanical structures it builds. It does not have any concept, at present, of multiple-support-upwards. It can deal with situations in which one object supports many others, as several stacks on a cube on a table; but it cannot handle such structures as bridges and arches in which one object is supported by several. When a child builds a high tower that turns out to be unstable, he has ideas about reinforcing it by providing multiple support to lower elements.

How hard is it to add such concepts? We do not really know, yet. At first it might appear very difficult to do incrementally because the data-structure in the original Blocks World assumed single support, and all the theorems about construction and interference between goals are written in terms of this single support. On further examination, by introducing a new idea of "compound object," many such problems disappear. Only time will tell how far such ideas will take us.

At the other extreme from the incremental approach would be one based on a concept of "micro-worlds" (referring to suborganization of knowledge, not to physically separate parts). The original Blocks World is an elegant "mini-theory" which, by itself, is a highly satisfactory model of certain kinds of interactions between purposes and physical relations. Is there no way to preserve its effectiveness, intact, in a larger system?

If the new area of meaning were very different, it would be much clearer what to do. If, for example, we wanted to talk about what the objects of the Blocks World were used for, (boxes are used to store things away that one does not expect to need soon, towers are used to make high structures, pyramids are not used for anything,) we would have little trouble. We could build a different micro-world about block structures, and their uses, and procedures for designing structures we needed for different purposes, and then turn to the Blocks World to find how to make the structures. Presumably, it would not be excessively hard to add to the system a collection of theorems and recommendations that would serve to tie the two separate micro-worlds into a system that could solve problems that need both kinds of knowledge.

Even this has not yet been done, however. So one of our objectives is to accumulate experience in finding ways to interconnect two comparatively separate micro-worlds. Another objective is to get experience in the kinds of problems involved in extending an existing micro-world. The interaction experience is somewhat more valuable because, if it can be done properly, the interaction advice may be able to survive the repeated extension of the micro-worlds involved.

There are other major activities in this laboratory, concerned with more immediate applications of new programming ideas. Most highly developed is our work on machine vision, which will be the subject of a subsequent article.

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Fog Modification Study Leads to Discovery of Stabilization Effect

A recent research effort to eliminate fog by a team of scientists from the Naval Research Laboratory (NRL) and Cornell Aeronautical Laboratory, Buffalo, N.Y., has led instead to the discovery of a chemical technique for stabilizing such meteorological mists.

(Continued on Inside Back Cover)

Self Regulation Through Biofeedback

Donald Woodward*
Office of Naval Research

Let us consider four typical situations that can face naval personnel. First, think of a man staring at a radar or sonar scope at the midpoint of a four-hour watch. It is the middle of the night, action is at a low level, the lights are dim, and for some reason he did not get eight hours of sleep. Even though he has been told that it is vitally important to make an instant report on any target he encounters, he finds himself feeling drowsy. Yet it is urgent that he maintain himself in a state of alertness.

In another situation, it is a bitter cold night that requires a man operating outdoors to wear gloves. Suddenly it is necessary to make a critical adjustment to a piece of gear that requires removing the gloves. His fingers, however, are too stiff and numb to perform the adjustment. He must somehow warm his hand quickly to get those fingers working.

Consider a more general situation of a man who has just completed a tension-ridden day. He needs to get some sleep to be ready for another equally tense day ahead of him. No sedatives are available or desirable, but he must relax himself into sleep.

Finally, these is the case where a man is approaching a moment of grave crisis. His palms are perspiring, and his heart starts beating rapidly, and yet he must remain calm and cool if he is to surmount the crisis successfully.

Scientific studies now underway indicate that an individual can develop the ability to dispel drowsiness in an instant and maintain full alertness, to warm his hands by increasing their temperature by several degrees, to relax tense muscles within minutes, and to calm the sensations of fear and nervousness. A number of experiments have been conducted successfully and replicated in other laboratories which clearly demonstrate that man can learn to control his internal body processes.

Actually there is nothing new in this concept. For hundreds of years yogis and other mystics of the Eastern world have demonstrated their apparent ability to control their heart beat, oxygen consumption, body temperature and other mental and bodily functions. Western man, however, until recently has ignored this concept in the belief that these were involuntary processes and not controllable through the conscious efforts of the individual. Modern textbooks, in fact, still maintain this viewpoint.

The accepted view of the nervous system actually harks back to ancient times and especially to Plato who thought man had a higher

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reasoning soul in the head and the lower souls in the body below. In scientific terms the human body is considered to be governed by two distinct and separate nervous systems. The first is the voluntary or cerebrospinal system of the greater brain which provides voluntary control of muscles by means of nerves traveling down the middle of the spinal column. We use this system to control our movements and speech. The second is the so-called involuntary or autonomic system of the lower brain consisting of a double chain of nerves running down either side of the spinal column. The responses of this system were considered to be largely automatic and independent of the cerebrospinal system.

Now there is very clear evidence that the distinction between voluntary and involuntary nervous systems is not as precise as was once thought, and that the responses of the autonomic system can be brought under similar kinds of control as motor-skeletal and verbal behaviors. The experiments have shown that various behaviors under control of the autonomic system can be modified through operant conditioning, that is, training by means of selective reinforcement (reward) procedures.

The key to all of this has been the recent development of a technique which makes teaching the control of internal body processes possible. This technique is known as biological feedback or biofeedback. Biofeedback is simply a procedure whereby the extremely minute changes that occur in the body are detected, amplified, and displayed to the individual or to others. Electrical variations in muscle, shifting brain wave patterns and, changes in temperature, heart rate, and blood pressure are all normally going on but we are not aware of them. By means of electronic sensors, capable of detection as little as a millionth of a volt, these changes are detected and we in turn can be made aware of them. The advent of biofeedback, in short, made it possible to know more about what is going on within an individual. Correspondingly, it became possible to tell the individual that he is progressing toward a change in state and thereby spur him to move closer to his goal.

The basic principle involved is not new. We learn to throw a ball by means of visual and neuromuscular feedback. You feel your arm move, see where the ball went and eventually correct your motion so as to get the ball where you want it. In like fashion, a sensor detects ongoing activity and presents the information almost instantly. This helps a person recognize the cues involved and thereby learn control.

As with most of the things in life, it is much easier to attain a goal if you know where you are now and if you have some way of knowing your success in reaching that goal. Feedback provides that information.

The discovery that physiological functions, formerly thought to be strictly involuntary, may be brought under control by conscious efforts has great relevance in medical therapy as well as in the study of basic phenomena of human physiology. It is also obvious that the potential ability of the individual to perform such feats as self regulation of brain activity, self induction of sleep, reduction of the disruptive effects of pain, autoregulation of skin temperature, or control of heart rhythm and blood flow is of great relevance to military activities. For this reason, the Office of Naval Research has underway a modest program of research aimed at investigating the potential and eventual application of these newly discovered phenomena. The work is being conducted at several institutions by leading researchers in the field of biofeedback. The following are examples of the investigations being carried out and some of the results obtained to date.

Heart Rate, Blood Pressure Control

For the past several years, Dr. David Shapiro and co-workers at Harvard University have been working primarily with cardiovascular functions, namely systolic and diastolic blood pressure and heart rate. Early in their work they found it necessary to develop instrumentation to measure and display instantaneously heart rate and blood pressure essentially beat by beat, without invading the body. With this instrumentation they were able to demonstrate that normal, healthy people could quickly learn to increase or decrease their heart rate at will. Following this, Shapiro and his group demonstrated that their subjects could learn to increase or decrease their systolic and diastolic blood pressures, the latter by 10 to 15% of baseline values after as few as one or two training sessions.

Throughout the foregoing work the heart rate or blood pressure was manipulated independently *i.e.*, either was modified without affecting the others so that one could increase blood pressure without increasing heart rate or vice-versa. Having considered the individual variable, the question arose as to what might be accomplished by combining variables in heart rate and blood pressure. That is, would it be possible to produce a combination of responses? To test his hypothesis, an experiment was performed involving four groups—one in which the heart rate and systolic blood pressure both increased, a second in which both decreased, a third in which the heart rate went up and blood pressure down, and a fourth in which heart rate down and blood pressure up. The results demonstrated a highly significant ability to learn to control both pressure and heart rate in a single session. The results also showed that it was easier to learn to make blood pressure and heart rate go together (both up or both down) than to make them go apart. In the latter case it was comparatively easier to learn to raise heart rate and simultaneously lower blood pressure than it was to lower heart rate and raise blood pressure.

Taken together these data demonstrate that it is possible to learn to selectively manipulate blood pressure or heart rate either singly or in combination. The extent to which this training can carry over into everyday life situations is presently under investigation. In this regard the procedures have been used to lower systolic blood pressure in patients with hypertension that has no apparent organic cause. A rather small number of subjects troubled by chronically cold feet have been able to learn to increase the temperature of their feet by means of feedback. While such results are impressive, the use of the techniques in further evaluating the interrelation between behavior and physiology may be much more significant in the long run. While pursuing that long range goal, however, it is encouraging to have a few immediately apparent and obviously relevant beneficial examples.

The work of Shapiro and his co-workers supported by ONR has been underway longer than that of the others we have under contract, and consequently has more hard data to report. The balance of examples are all funded by the Defense Advanced Research Projects Agency (ARPA) through ONR and have been underway for only two years. Their results correspondingly are more tentative but none the less promising and exciting.

The work being done under the ARPA funding is spread among ten institutions from the east to the west coast. Strictly speaking, not all of it is concerned with only the autonomic nervous system. As discussed later, some of it is concerned with brain waves. All of the work, however, is concerned with self regulation of events of which we are normally not aware, and all of the investigators are using feedback in one form or another.

Hand Temperature

Dr. Edward Taub at the Institute for Behaviorial Research has been working with techniques to enable people to establish voluntary control of their own skin temperature. To date, he has been working with the back of the hand temperature, using thermistor probes appropriately placed on each hand. The individual is seated in a reclining chair in a dimly illuminated, sound proof room, and told what is involved. At the end of each 15 minute session, he is shown how well he has done. Feedback was in the form of a light, located at eye level, which varied in brightness directly with changes in skin temperature in the dominant hand. Training was directed at manipulating temperature in the dominant hand. Under this procedure more than 20 subjects were able to learn to increase or decrease skin temperature. The average temperature changes were from 2°F to 4.5°F in either direction—thus a range of 4° to 9°F.

Interestingly, during early training periods the temperature of the nondominant hand tends to decrease or increase at the same time as the dominant hand temperature goes down or up. However, after training the change is restricted to the dominant hand—the other hand remaining at or about baseline levels. As with just about everything else in the world, some people are better at this control than others. Thus the four best subjects were able, on command, to increase temperature 4 to 8°F, return to the baseline, and then decrease temperature 4 to 8°F—twice the average previously noted all in a matter of minutes.

Of great significance is the fact that some of the subjects trained to autoregulate the temperature of the back of the hand in the laboratory were able to maintain the autoregulatory ability in a new location. In July 1972, three of Dr. Taub's subjects were taken to the Army Institute of Research for Environmental Medicine (ARIEM). Here the subjects carried out three types of experiments: (1) temperature increase in a cool environment (55°F) wearing normal street clothing; (2) autoregulation of heart output in a constant temperature water-calorimeter bath and (3) autoregulation in a frost nip apparatus. The ARIEM experiments demonstrated that the subjects can produce autoregulatory increases in temperature in a cold environment and can do so even after constriction of the blood vessels has set in. In fact, by some measures, performance in the cold was better than in normal room temperature. Preliminary evidence even suggested that autoregulatory processes may be of aid in increasing the temperature of fingers inserted in a front-nip apparatus, thus possibly aiding in increasing manual dexterity in the cold and in protection against some types of freezing injuries. One subject demonstrated retention of autoregulatory ability after a lapse in training of about one year. Furthermore, all three previously trained subjects were able to autoregulate without resorting to feedback.

Effect of Prolonged Changes

Quite naturally when we are involved in manipulating events such as blood pressure, heart rate, and blood flow, there is an understandable concern that large and/or prolonged changes might be harmful to the organism. Thus, as a precautionary measure, Dr. Alan Harris and his colleagues a Johns Hopkins Medical School worked with primates to test the limits of organismic capability and tolerance levels. What they have found—initially—is that elevations of diastolic blood pressure on the order of 50-60 mm Hg above resting levels (70-80 mm Hg) can be obtained on signal up to 70 times a day, for several minutes each time. However, the animals could not maintain this control for more than a few days. Following this, two other animals were trained to raise diastolic pressure 3 to 5 mm Hg and maintain this elevation 23 hours per day. After two weeks both animals were maintaining 10 to 15 mm Hg. elevations for 23 hours a day, 7 days a week. At this point both animals showed signs of physical distress including fatigue and weight loss, and the procedure was discontinued. Following this, another two animals were trained to achieve and maintain diastolic pressure 35 to 40 mm Hg above baseline levels on a 12 hour on, 12 hour off schedule. They were able to maintain this schedule for some weeks without any apparent adverse effects.

Taken together these studies suggest (1) that dramatic changes can be achieved but if they are quite rapid the organism loses control, (2) if more moderate but prolonged—*i.e.*, 23 hours/day—the organism becomes physically distressed, and (3) large changes—gradually achieved—can be maintained for weeks.

Self control or self-regulating behavior through biofeedback training is by no means confined to the autonomic system. Work on muscle relaxation control is underway at the University of Colorado Medical School under the direction of Dr. John Stoyva and Dr. Thomas Budzinsky.

These investigators are asking questions such as the following: first, can biofeedback training in profound muscle relaxation be of assistance in helping an individual to achieve a drowsy and/or sleep state at will. Secondly, can such training in attaining states of prolonged relaxation and lower arousal be useful in moderating the individuals reaction to external stress? For example, could a healthy individual maintain a state of moderate or low arousal in spite of noxious external stimuli such as loud noises, flashing lights, or other adverse stimuli?

Third, could training in profound relaxation assist the individual in his ability to return quickly to moderate levels of arousal after the passing of a dangerous or stressful episode which has produced a high arousal condition? In other words, can this kind of training produce faster recovery from stress in the individual? Fourth, can the benefits of such training be detected in a man's performance? Could it be demonstrably useful in helping the individual maintain an arousal level appropriate for a given task? For example, it would be expected that optimal arousal level should be higher for a quarter-mile run that it would be for the sustained operation of complex equipment.

Muscle Feedback

The main focus of a recent study at Colorado was to explore the most efficient means of teaching an individual to voluntarily produce relaxation and drowsy sleep-like state. Experiments centered on whether relaxation produced by electromyography (EMG) feedback training in a one muscle group will generalize to other bodily muscle groups and possibly assist them. (The EMG measures muscle electric potential.) It turns out that forehead feedback training proves superior to forearm feedback training. In the latter only the arm is relaxed, whereas relaxation will apparently generalize from the forehead muscle to other muscles in the body and correspondingly can be expected to have a beneficial affect on other muscle activities.

Perhaps most significant for practical purposes was the finding that EMG feedback training and muscle relaxation is most useful to subjects with high starting levels of muscle tension. In other words, subjects who are already relaxed do not benefit from EMG feedback training. At the same time, subjects who are tense or who show a greater degree of muscle tension can learn to relax effectively. The extent of this beneficial activity has yet to be determined and is the subject of future work.

Brain Waves

Probably the most exotic research underway in the area of biofeedback training involves control of brain waves, particularly alpha and beta. The work of Dr. Jackson Beatty at the University of California at Los Angeles has demonstrated that subjects may reliably increase the proportion on either alpha or beta activity in their brain waves even when they have no prior knowledge of the nature of the experiment or the variable involved. What this means is simply that the people can learn to vary these brain waves without being aware of exactly how they are doing it.

After Beatty had established the ability of individuals to increase their brain activity at will, he turned to the question of whether such activity has concurrent effects upon heart rate and respiration. He found none, which argues for the relative independence of the cerebral and autonomic systems. Simply stated, it means that brain waves, heart rate and respiration can all be varied independently and therefore are not necessarily tied together as some have previously supposed.

Although it cannot be argued that the two systems are totally unrelated, it can at least be stated that the connection between EEG activity and the psychological state is not as strong as has been previously assumed. Finally, Beatty's experiments seem to rule out the possibility that the heart rate and respiratory system are affected by changes in brain activity.

Another set of experiments by Beatty were concerned with the environment for generating alpha and beta waves. He found that it is easier to do this in a darkroom with the eyes closed, but that once the technique is learned, individuals can control the production of such brain waves even with the lights on and the eyes open.

Beatty's planned next step is to determine whether or not the voluntary control of such states as alpha and perhaps the arousal state can have a significant effect on the performance of practical tasks. He will look at tasks involved in vigilance, monitoring or decision tasks, discrimination tasks, and learning or memory tasks as they relate to variation in the alpha and/or beta waves. An example is the performance in a watchkeeping task of a sonar or radar operator which varies as a function of time.

Various drugs such as the amphetamines can, of course, stimulate a man to alertness. What Beatty hopes to find out is to what extent voluntary change in the central nervous system (that is, the alpha or beta waves or others) can achieve the same effect as an arousal-producing drug and improve vigilance performance.

The great potential of the ability to control the output of one's own brain waves is further indicated by the advanced work of Dr. Joe Kamiya and his associates at the Langley Porter Neuropsychiatric Institute, San Francisco. He has been concerned specifically with techniques to increase both the amplitude and density of alpha waves at the same time. Like many other investigators in the field, he has been able to obtain surprisingly higher average scores with training.

Visual Processing

Dr. Kamiya has made an interesting finding related to the alpha waves and the visual process. Normally the alpha waves are blocked during reading. He discovered, however, that relatively fast readers demonstrated a consistently higher average alpha amplitude while they were reading as opposed to the time they were simply looking at the laboratory wall. This suggests that the alpha rhythm may be a way of developing high visual processing. If this work can be repeated with appropriate controls, it could lead to pioneering studies on the relationship of visual attention, detection and identification with the presence of alpha.

Perhaps an even more exciting aspect of Kamiya's work has been stimulated by the work of some other investigators indicating that the two hemispheres of the brain responds differently to verbal tasks and to spatial tasks. Typically the left hemisphere tends to respond more with verbal and verbal-like tasks while the right hemisphere seems more involved with spatial relationship. Following up on this with special EEG hookups, Kamiya and others at Langley Porter have been able to demonstrate that indeed there are different waves associated with spatial and with verbal tasks and these are differentially represented in the different hemispheres. Again this work is being repeated, but it holds out the exciting prospect that it might allow us to program specific sorts of learning in specific ways and thereby reduce remarkably the time required for learning to take place.

Kamiya is also looking at the possibility of determining whether the cerebral and autonomic systems correlate in achieving various good and poor levels of performance in tasks involving reaction time, word memory, visual pattern detection and so forth. The hope is that if such a correlation exists, one can use feedback training to enable the subject to maintain a specific correlated state and thereby improve performance.

Summary

The above described experiments and other investigations have demonstrated that, at least in a laboratory situation, human subjects can augment alpha, beta, and probably theta EEG frequencies on command; increase or decrease skin temperature, heart rate and blood pressure; learn systematic relaxation of muscle tension and decrease existing higher-than-normal levels of muscular tension or blood pressure quite readily; and learn to manipulate selectively activities in different brain areas so as to make them more coherent.

Finally, it should be noted that these results, encouraging as they are, have not yet reached the point where naval personnel can routinely use biofeedback in stressful situations to prevent frostbite, maintain a high level of vigilance, relieve tension, *etc*. Much work remains to be done, but at least a significant beginning has been made.

High Temperature Lubricants for Jet Engines

A program is underway at the Naval Research Laboratory (NRL) to identify and characterize synthetic lubricating fluids which can withstand the high temperatures created in jet engines.

A promising candidate as a lubricant for transonic jet engines is a fluid consisting primarily of polyphenyl ethers. This material is stable in air to 270°C, but by itself would be marginal for higher output engines. When the unprotected fluid is heated above 270°C in air, it rapidly degrades to a viscous, dark fluid or solid containing long-life free radicals, hydroperoxides, and polymers.

Recent work at NRL has demonstrated, however, that by the addition of small quantities of essentially insoluble basic salts of the alkali metals or barium, this fluid can be stabilized at a temperature of at least 370°C in the presence of air. The protected fluid remains clear, its viscosity increases only slightly, and few, if any, radicals, peroxides, or higher polymers are generated.

NRL scientists recently synthesized soluble organic alkali and alkaline earth salts, which appear to similarly stabilize the oxidation of polyphenyl ethers. The synthesis of these salts provides a means for measuring the degree of protection afforded by the salts, and examining the mechanism by which they operate as inhibitors of oxidation degradation.

Ice Breakup in an Arctic Delta

H. J. Walker*
Louisiana State University

The Colville River, the longest river in northern Alaska, originates in the Brooks Range and crosses the Arctic Foothills and Coastal Plain before entering the Arctic Ocean. The delta it has produced is 550 km^2 in area and is actively growing today. The Colville is one of the best examples of a true arctic river, *i.e.*, a river which ceases flow in winter (1). Rivers which originate outside the Arctic, such as the Mackenzie of Canada and the Yenisey of Siberia, continue to flow during winter even though their surface is covered with up to 2 meters (m) of ice. Rivers with drainage basins entirely within the zone of continuous permafrost, however, cease flowing because of the freezing of both their surface-water and ground-water sources.

This cessation of flow affects the delta and its waters in several ways. One of the most important results of flow stoppage is that the brackish water of the delta's channels and the ocean immediately seaward of the delta is replaced with sea water.

Just prior to breakup, which usually occurs in the first week of June, the environment of the Colville Delta has the following characteristics: approximately 2 m of ice over all bodies of water including lakes, distributary channels and ocean; bottom-fast ice in water bodies less than about 2 m deep; river water (including ice cover) at a low stage; no water movement except tidal action; highly saline water at the front of the delta beneath the ice; and little hydrologic, oceanographic or morphologic activity.

For purposes of reporting sequentially what happens during this time of year, the flooding season has been divided into 3 short and unequal periods; namely: prebreakup flooding, breakup flooding and postbreakup flooding. Prior to 1971, the processes and changes occuring during these periods were observed only from the ground at the Naval Arctic Research Laboratory field camp at the head of the delta because of logistic difficulties. In 1971 a helicopter was available and made it possible for the first time to follow the movement of both ice and water during these critical periods of time (Figure 1). This field work, which was supported by the Arctic and Geography Programs of the Office of Naval Research, provides new insight into the nature of arctic deltaic processes.

* Dr. Walker is Assistant Professor of Geography and Anthropology at Louisana State University. Formerly Dr. Walker was a geographer for the Office of Naval Research and Liasion Scientist for ONR, London.

Figure 1 — Sea-ice station established by helicopter, 12 km north of Colville Delta front

Prebreakup flooding is initiated a few days after snowmelt begins to accumulate on the river ice. The prebreakup flood-waters flow over the areas of bottomfast ice and cause the areas of floating ice to fluctuate up and down with stage (Figure 2).

The first floodwater, which is the result of the first melting of the snow, contains little suspended mineral or organic matter. However, as snow-melt increases and the active layer begins to develop, the suspended load of the river increases rapidly.

As the floodwater moves seaward it flows both over and under the sea ice just as it does with river and lake ice. That flowing over the sea ice eventually drains through holes (sea ice moulins) and cracks in the ice and joins the water flowing northward in deltaic channels beneath the ice (2). In 1971, during the time of maximum flooding 140 drainage holes were observed along the leading edge of the over-ice floodwater (3).

Prebreakup flooding continues until the river ice begins to move downstream at which time breakup flooding is initiated. This period is very short, usually lasting only about 2 days at any one point along the river. However, the timing of breakup at various points in the delta differs. Usually it is about 3 days later at the mouth of the river channels than at the head of the delta, 40 km upstream.

Figure 2 — The prebreakup floodwaters flow over the areas of bottom-fast ice and cause the areas of floating ice to fluctuate up and down with stage

The duration and nature of postbreakup flooding reflects the amount of snow left after breakup and the rate at which it melts. During most years this period ends in mid-June. Thus, the time from the first river-water movement to the end of postbreakup flooding is less than a month (Figure 3). Although the period is short it is the time of the year when hydrologic and morphologic processes are most active.

One of the first results of renewed river flow is the flushing of the saline water from the river channels. This flushing action occurs quite rapidly as evidenced by the fact that the river changes from a highly saline to a completely fresh condition in a period of only a few hours (4).

As floodwater moves into the ocean it proceeds beneath the sea ice in the shape of a wedge. The advancement of this wedge was monitored in 1971 by making salinity measurements from stations established on the ice (Figure 2). Within 12 days (by 9 June) after floodwater had reached the front of the delta the freshwater wedge had moved seaward as much as 40 km (Figure 4). By this time the area in Harrison Bay occupied by floodwater was 2,650 km². The freshwater-seawater interface of the advancing wedge was sharp. Salinities changed from less than 8 ‰ to 30 ‰ within depth differences of less than 50 cm (3). Further, the interface was very stable as shown by densimetric Froude

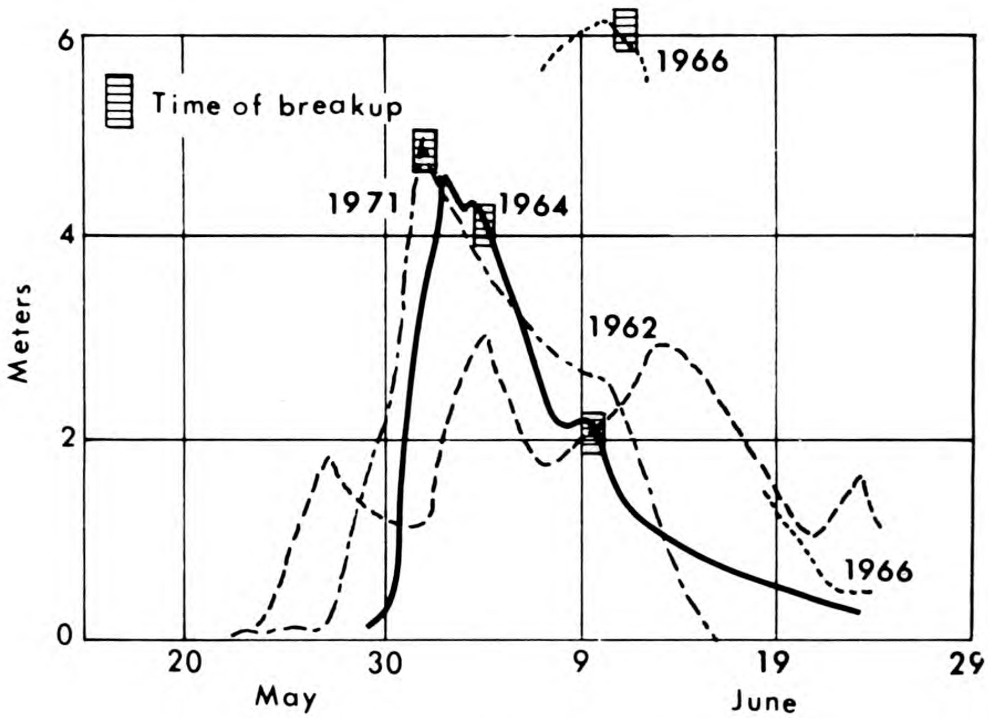

Figure 3 — Stage at head of the Colville Delta during flooding for selected years

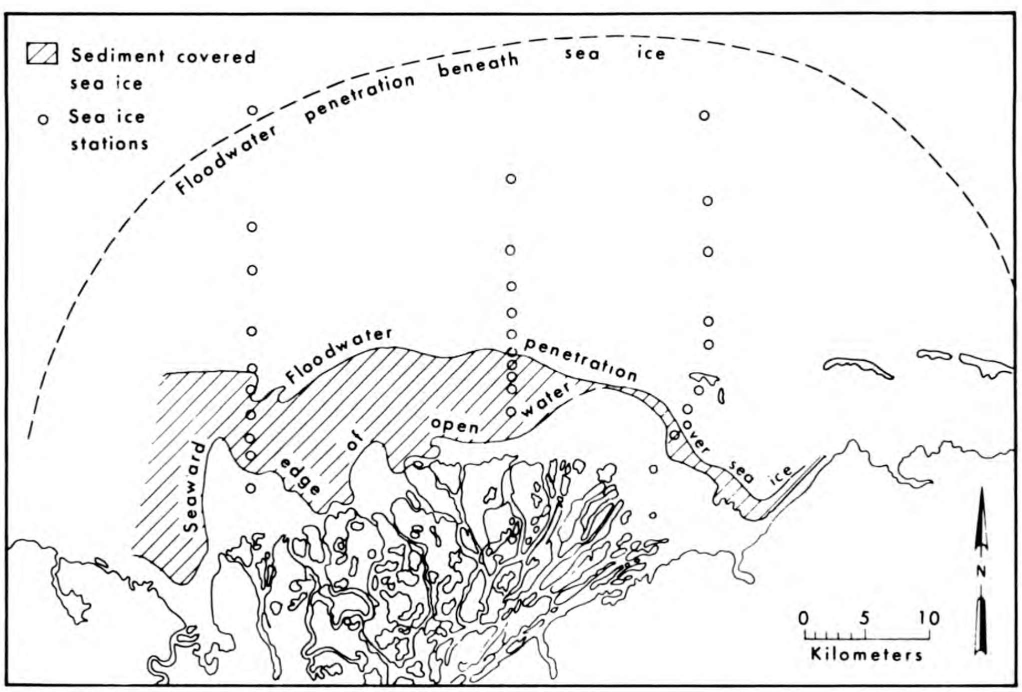

Figure 4 — Map showing position of floodwater in Arctic Ocean on 9 June 1971

numbers of less than 0.006. The sharp interface and the complete replacement of the sea water at the front of the delta made it possible to calculate the amount of water displaced and therefore the discharge of the river during breakup. In 1971, by 9 June (the last day the helicopter was available) the sea water displaced amounted to $4.87 \times 10^9 m^3$. Although this was only 12 days after flooding had begun it was so great that nearly half of the total discharge for 1971 had already flowed to the ocean. By the time spring floods ceased 5 days later, 55 per cent of the total flow for the year, 9.91 km^3, had occurred (3).

Whereas the spring floods account for about half of the annual discharge, the proportion of the annual suspended load that they carry seaward is even greater, being on the order of 75 per cent. Much of this sediment is deposited before breakup on sandbars, mudflats, and bottom-fast ice in river channels, lakes and sea ice (Figure 5). The amount varies greatly and deposits may be quite thick in enclosed basins such as lakes, in channels where flow reverses with stage, or on sea ice where a decrease in velocity accompanies the fan-like spreading of the floodwater as it moves from river channels. In 1971 the maximum thickness measured was 17 cm on the sea ice 6 km north of the eastern part of the delta

Figure 5 — Sea ice 8 km offshore. Shown are the channels eroded into the surface of the ice as floodwater drained through the hole in the upper right. Also shown is the sediment deposited by floodwaters.

front. Sediment deposited on the ice in lakes eventually is dropped to the bottom as the ice melts. That deposited on river ice is carried seaward once the ice breaks loose from the bottom, and deposits on the sea ice at the front of the delta are either dropped in place as the ice melts or carried away from the delta when the sea ice breaks up. The actual amount removed in this way varies from year to year. However, to date photographic monitoring of sea ice breakup has not been sufficiently frequent to form an accurate estimate of the amount carried away from the delta.

Breakup is the most dynamic period of time in arctic delta formation. However, it is precisely this period of time during which surface movement is impossible. Thus, in order to collect samples, monitor instruments, and generally observe the hydrologic, oceanographic and morphologic processes operating during breakup, helicopters are indispensible. In 1971 the availability of a helicopter, even though for only 10 days allowed the acquisition of data about the Colville River Delta that were previously unobtainable. Analyses of these data have provided new insight into the nature of arctic deltaic processes.

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Kaman Receives Follow-On Stapl Contract

Kaman Aerospace Corporation, subsidiary of Kaman Corporation, will demonstrate the feasibility of its Ship Tethered Aerial Platform (STAPL) concept under a contract recently awarded by the Office of Naval Research.

Under the contract, Kaman will design, fabricate, flight test and evaluate two unmanned autogyro aircraft configured with automatic flight control systems and data recording equipment. The self-contained automatic flight control system engineered by Kaman will provide three axis stabilization and automatic flight path control and contain the necessary redundancy for mission reliability.

Kaman performed concept analysis, feasibility studies and preliminary design planning on STAPL under an initial ONR contract two years ago. The tethered system has potential for several applications requiring an elevated platform.

On the Naval Research Reserve

NRRC 9-21, Denver, Colorado Wins National Award

Rear Admiral C. O. Holmquist, USN, Chief of Naval Research, announced that this year's winner of the *A. Hoyt Taylor Award* was NRRC 9-21, Denver, Colorado. Presentation of the award is planned for early 1973.

The award is given to the company deemed most outstanding from nominations submitted by Commandants of the Continental Naval Districts. The winner, from 65 Research Reserve Units in competition, was selected by a panel composed of the following officers:

CAPT J. E. O'Neil, USNR
Director, Naval Reserve Programs Division
Bureau of Naval Personnel

CAPT F. Sallada, USN
Director, Naval Applications and Analysis Division
Office of Naval Research

CAPT H. C. Craig, USNR
Deputy for Naval Reserve
Office of the Assistnat Deputy Chief of Naval
Operations (Naval Reserve)

Among the notable accomplishments of NRRC 9-21 for Fiscal Year 1972 were the following:

Ready Reserve Status	100%
Satisfactory Federal Year Completion	92%
Drill Attendance	92%
Membership, Net Increase	+14
Scientific & Technical Studies	4 approved studies underway

Members of the panel commented favorably on the records of the other companies entered in the competition. These companies were as follows:

1-1	Boston, Massachusetts	6-17	Huntsville, Alabama
3-4	Rochester, New York	8-4	Houston, Texas
4-7	Columbus, Ohio	11-5	San Diego, California
5-8	Washington, D.C.	12-3	Sunnyvale, California
13-1	Seattle, Washington		

Research Notes

Ceramic Sonar Transducers

Scientists at the Naval Research Laboratory (NRL) developed a technique to improve the reliability and durability of ceramic sonar transducers.

In an investigation of fabrication techniques and the effects of additives or alloying agents on the properties of barium titanate ($BaTiO_3$), a simple ceramic sonar-transducer material, NRL investigators found that small additions of lithium fluoride (LiF) improved densification (lowered the porosity). Furthermore, when the LiF was combined with comparable additions of magnesium oxide (MgO), increases in strength of 50 to 200 percent were achieved.

The results were obtained by first hot-pressing the material under reducing conditions and then applying an oxidizing anneal. More recently, substantial increases in strength were achieved by the more economical process of sintering the $BaTiO_3$ with the combined additives.

The use of piezoelectric ceramics as the transmitting and/or sensing elements in sonar transducers is one of the more important naval applications of ceramics. Unfortunately, these ceramic elements are prone to mechanical failure under shock conditions, thus posing a serious problem.

The NRL studies show that by eliminating the major inhomogeneities through application of the densification techniques developed for $BaTiO_3$, the strength of the average transducer ring can be doubled and variations in strength greatly reduced.

In addition, alloying, as described with $BaTiO_3$, and the possibility of reinforcement with fibers, may offer further opportunities to improve the strength and reliability of sonar transducers.

New Mass Spectrometry Applications

Although mass spectrometry has been usefully employed in the study of inorganic chemistry for a number of years, scientists at the Naval Research Laboratory, in collaboration with the University of Pennsylvania, are studying mass spectral applications for elemental analysis, metastable ion defocusing, negative ion studies, chemical ionization and field ionizations.

The mass spectrometer has potential for many uses beyond the simple identification of molecules.

It can be used to estimate rates of reactions, measure heats of formation, bond energies, clastogram studies, identification of neutral species, proton and electron affinities and many other fundamental physical parameters.

These data may be used in tailoring new inorganic molecules for many practical applications, namely: thermal resistant polymeric materials and high density fluids.

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The Navy and the Challenge of Deep Diving, Rear-Admiral C. O. Holmquist, March

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VIII. Space Sciences Division*

Major Solar Eruption Observed, R. Tousey, G. E. Brueckner, M. J. Koomen and D. J. Michels, January
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*A division of Naval Research Laboratory, Washington, D.C.

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(*Continued from Page 13*)

In explaining their results, the scientists reported that the release of certain organic compounds into the atmosphere from natural or anthropogenic sources could increase the lifetime of clouds and fogs. Thus it might be possible to use this method to change the intensity and distribution of rainfall by the introduction of film-forming chemicals into cloud systems.

There had been earlier reports from some atmospheric scientists that selected film-forming chemicals could be introduced into the atmosphere to decrease the intensity of fog and thus eliminate it as a menace to air and auto traffic, and other hazards.

Their premise was based on the ability of surface-active organic compounds to form monomolecular films on condensation nuclei and fog drops, which would slow the growth rates of water drops during the formative stages of fogs.

NRL scientist William D. Garrett of the Ocean Sciences Division collaborated with W. C. Kocmond and E. J. Mack of the Cornell Aeronautical Laboratory in a study to check this theory by dete mining the exact influence of various organic film-forming chemicals on the properties of fogs.

Surprisingly, the scientists found from their research that, in contrast to the expected diminution of fog intensity, the chemicals instead actually stabilized the fogs.

In their investigations, the scientists produced man-made fogs under highly controlled conditions in a large chamber near Buffalo, which were sealed at various stages of formation with the "vapor-barrier" film-forming chemicals.

Results showed that the chemical would not limit fog formation, but that the treated fogs were significantly stabilized since the evaporation rates of the fog drops were greatly reduced by the vapor barrier effects of the organic film.

The interesting point of the research, the scientists reported, was the fact that although fog breaking does not occur with this treatment, fogs and clouds can be stabilized against evaporation by injections of film-forming agents.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Arlington, Va. 22217. Requests for subscriptions should be directed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price, $3.00 per year in the U.S. and Canada; $3.75 per year, foreign; $0.35 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

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Cover Caption

Artists concept of the robot being developed by M.I.T. which will be able to survey its environment and move about in it under control of natural English instructions.

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