08. [Introduction]
From *Augmenting Human Intellect*
A Conceptual Framework

Douglas Engelbart invented many of the defining features of the computer interfaces we work with each day, including the mouse, the window, and the word processor. He helped establish the Internet, made the first serious investigation of computer-supported cooperative work, first demonstrated videoconferencing and mixed text/graphic displays, created structured programming editors and used remote procedure calls in the 1960s, and independently invented the hyperlink at the same time the idea was being hatched by Ted Nelson (◊11).

In short, Engelbart is one of the great inventors of the 20th century. Unfortunately, in addition to being largely unrecognized, he is also one of the most misunderstood figures in new media. Few who know him as "the inventor of the mouse" realize that Engelbart's inventions have never been widely used to pursue the goals that motivated his work in the first place. His inventions to date represent only the first steps of an unfulfilled vision, one summed up in the title of this report, "Augmenting Human Intellect." In 1988, in *A History of Personal Workstations,* Engelbart told the story of his decision to pursue this path:

> I was doing odd-job electrical engineering work at Ames Research Laboratory in Mountain View, California, with the National Advisory Committee for Aeronautics (NACA, forerunner of NASA). For several months I had been devoting most of my spare time to searching for professional goals; for some reason I wanted to invest the rest of my heretofore aimless career toward making the most difference in improving the lot of the human race. . . .
>
> Suddenly, up through all of this delightful, youthful abstraction bobbed the following clear realization: The complexity of the human situation was steadily increasing. Along with the increasing complexity had come a general increase in the urgency associated with the more critical problems. . . .
>
> FLASH–1: The difficulty of mankind's problems was increasing at a greater rate than our ability to cope. (We are in trouble.)
>
> FLASH–2: Boosting mankind's ability to deal with complex, urgent problems would be an attractive candidate as an arena in which a young person might try to "make the most difference." (Yes, but there's that question of what does the young electrical engineer do about it? Retread for a role as educator, research psychologist, legislator, . . . ? Is there any handle there that an electrical engineer could . . . ?)
>
> FLASH–3: Ahah—graphic vision surges forth of me sitting at a large CRT console, working in ways that are rapidly evolving in front of my eyes (beginning from memories of the radar-screen consoles I used to service).
>
> The imagery of FLASH–3 evolved within a few days to a general information environment where the basic concept was a document that would include mixed text and graphic portrayals on the CRT. The imagery carried on to extensions of the symbology and methodology that we humans could employ to do our heavy thinking. There were also images of other people at consoles attached to the same computer complex, simultaneously working in a collaboration mode that would be much closer and more effective than we had ever been able to accomplish.
>
> Within weeks I had committed my career to "augmenting the human intellect" (188–189).

In Engelbart's view, the most effective humans are already augmented. (For example, a typewriter makes the process of writing faster.) He dubbed this augmentation, in the context of which he proposed to do his work, the H-LAM/T *system. H-LAM/T stands for "Human using Language, Artifacts, Methodology, in which he is Trained." Each of these terms is explained in section II.A of the report:*

1. Artifacts—physical objects designed to provide for human comfort, for the manipulation of things or materials, and for the manipulation of symbols.
2. Language—the way in which the individual parcels out the picture of his world into the concepts that his mind uses to model that world, and the symbols that he attaches to those concepts and uses in consciously manipulating the concepts ("thinking").
3. Methodology—the methods, procedures, strategies, etc., with which an individual organizes his goal-centered (problem-solving) activity.
4. Training—the conditioning needed by the human being to bring his skills in using Means 1, 2, and 3 to the point where they are operationally effective.

2 Within the H-LAM/T system, Engelbart discusses the augmented human's repertoire of capabilities as a "toolkit"—a discussion of the human in mechanical terms that recalls Norbert Wiener's formulations of cybernetics (◊04).

Engelbart quit his job, earned a Ph.D., went to work at the Stanford Research Institute (SRI), and began to pursue funding for his augmentation research program. Two years after joining SRI (in 1959) he had partial support for his time. The next year he was full-time on augmentation, and in 1962 he filed the historic report excerpted here—the first major fruit of FLASH–3.

Some of the most stirring, most prescient sections of Engelbart's report are told in the style of a "graphic vision" (that is, in the style of science fiction) and are narrated in the second person. Other styles found in the report include a relatively standard reporting style, personal reflection on his modes of working, a speculative voice, and a dense investigation of the human augmentation system. The last of these is the most challenging to read; serious students and practitioners of new media will benefit from reading Engelbart's entire report, included on the CD. The excerpts here represent some of the most useful starting points for this work.

These excerpts are situated within the report's overall framework. The first excerpt combines a general introduction to the report with a vision of "process augmentation" for an architect (offered before Nicholas Negroponte's famous *The Architecture Machine* and its follow-up *Soft Architecture Machines,* ◊23). The second excerpt includes Engelbart's discussion of Vannevar Bush's "As We May Think" (◊02) and of experiments Engelbart undertook along memex lines using paper notecards. (These experiments may remind one of Xerox PARC's Notecards system, or of a passage found in Walter Benjamin's Reflections that is well-loved by hypertext theorists: "And today the book is already, as the present mode of scholarly production demonstrates, an outdated mediation between two different filing systems. For everything that matters is to be found in the card box of the researcher who wrote it, and the scholar studying it assimilates it into his own card index" (78).) Finally, a portion of Engelbart's second-person narration of future technology is included. Rather than also excerpt the dead-on specification for what we would come to know as the word processor, these selections include powerful descriptions of capabilities most computers still do not have, 40 years later. Some of these capabilities relate closely to today's research—including the Fisheye Views generalized by George Furnas and link types (which enable links to play a greater variety of informational roles than being jump markers). Since Engelbart, link types have been investigated by many working in hypertext. While they have failed to gain the popularity that the monolithic link of the Web has gained, they may come into more popular use if the W3C's XLink or a related standard is successful.

More discussion of Engelbart's work, and its history, is included in this volume's introduction to his 1968 paper with William English, "A Research Center for Augmenting Human Intellect." (◊17)
—NWF

17 Engelbart's report proposed to make improvements to the artifacts of this system, specifically with computer technology, that would
3 enable new effectiveness throughout the system. Because Engelbart, in 1962, could only speculate about effective augmentation means (in ways that were remarkably correct), he also included examples of de-augmentation. One of the most amusing, of which an illustration is included here, is that of de-augmenting the writing process.

Although this report is obscure when compared to Engelbart's widely-adopted inventions, Engelbart considers the conceptual framework outlined here his most significant contribution to the field of new media. As he discusses in A History of Personal Workstations:

[W]hat I came to realize is that there is only one, clearly dominant factor that underlies essentially every cause for any uniqueness that I might list for historical record. It isn't a technology, it isn't a science, and it isn't a marketing or business model ... It is what I call my "Framework." My Framework is based upon an intuitive conviction, implanted in my head (apparently permanently) over 30 years ago, that the gains in human knowledge-work capability that we will achieve by properly harnessing this new technology will be very large. Metaphorically, I see the augmented organization or institution of the future as changing, not as an organism merely to be a bigger and faster snail, but to achieve such new levels of sensory capability, speed, power, and coordination as to become a new species—a cat.

Further Reading

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Original Publication

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Augmenting Human Intellect

A Conceptual Framework

Douglas Engelbart

I Introduction

A General

By "augmenting human intellect" we mean increasing the capability of a man to approach a complex problem situation, to gain comprehension to suit his particular needs, and to derive solutions to problems. Increased capability in this respect is taken to mean a mixture of the following: more-rapid comprehension, better comprehension, the possibility of gaining a useful degree of comprehension in a situation that previously was too complex, speedier solutions, better solutions, and the possibility of finding solutions to problems that before seemed insoluble. And by "complex situations" we include the professional problems of diplomats, executives, social scientists, life scientists, physical scientists, attorneys, designers—whether the problem situation exists for twenty minutes or twenty years. We do not speak of isolated clever tricks that help in particular situations. We refer to a way of life in an integrated domain where hunches, cut-and-try, intangibles, and the human "feel for a situation" usefully co-exist with powerful concepts, streamlined terminology and notation, sophisticated methods, and high-powered electronic aids.

Man's population and gross product are increasing at a considerable rate, but the *complexity* of his problems grows still faster, and the *urgency* with which solutions must be found becomes steadily greater in response to the increased rate of activity and the increasingly global nature of that activity. Augmenting man's intellect, in the sense defined above, would warrant full pursuit by an enlightened society if there could be shown a reasonable approach and some plausible benefits.

This report covers the first phase of a program aimed at developing means to augment the human intellect. These "means" can include many things—all of which appear to be but extensions of means developed and used in the past to help man apply his native sensory, mental, and motor capabilities—and we consider the whole system of a human and his augmentation means as a proper field of search for practical possibilities. It is a very important system to our society, and like most systems its performance can best be improved by considering the whole as a set of interacting components rather than by considering the components in isolation.

This kind of system approach to human intellectual effectiveness does not find a ready-made conceptual framework such as exists for established disciplines. Before a research program can be designed to pursue such an approach intelligently, so that practical benefits might be derived within a reasonable time while also producing results of long-range significance, a conceptual framework must be searched out—a framework that provides orientation as to the important factors of the system, the relationships among these factors, the types of change among the system factors that offer likely improvements in performance, and the sort of research goals and methodology that seem promising.*

In the first (search) phase of our program we have developed a conceptual framework that seems satisfactory for the current needs of designing a research phase. Section II contains the essence of this framework as derived from several different ways of looking at the system made up of a human and his intellect-augmentation means.

The process of developing this conceptual framework brought out a number of significant realizations: that the intellectual effectiveness exercised today by a given human has little likelihood of being intelligence limited—that there are dozens of disciplines in engineering, mathematics, and the social, life, and physical sciences that can contribute

*Kennedy and Putt (see Ref. 1 in the list at the end of the report) bring out the importance of a conceptual framework to the process of research. They point out that new, multi-disciplinary research generally finds no such framework to fit within, that a framework of sorts would grow eventually, but that an explicit framework-search phase preceding the research is much to be preferred.

improvements to the system of intellect-augmentation means; that any one such improvement can be expected to trigger a chain of coordinating improvements; that until every one of these disciplines comes to a standstill *and* we have exhausted all the improvement possibilities we could glean from it, we can expect to continue to develop improvements in this "human-intellect" system; that there is no particular reason not to expect gains in personal intellectual effectiveness from a concerted system-oriented approach that compare to those made in personal geographic mobility since horseback and sailboat days.

The picture of how one can view the possibilities for a systematic approach to increasing human intellectual effectiveness, as put forth in Section II in the sober and general terms of an initial basic analysis, does not seem to convey all of the richness and promise that was stimulated by the development of that picture. Consequently, Section III is intended to present some definite images that illustrate meaningful possibilities deriveable from the conceptual framework presented in Section II—and in a rather marked deviation from ordinary technical writing, a good portion of Section III presents these images in a fiction-dialogue style as a mechanism for transmitting a feeling for the richness and promise of the possibilities in one region of the "improvement space" that is roughly mapped in Section II.

The style of Section III seems to make for easier reading. If Section II begins to seem unrewardingly difficult, the reader may find it helpful to skip from Section II-B directly to Section III. If it serves its purpose well enough, Section III will provide a context within which the reader can go back and finish Section II with less effort.

In Section IV (Research Recommendations) we present a general strategy for pursuing research toward increasing human intellectual effectiveness. This strategy evolved directly from the concepts presented in Sections II and III; one of its important precepts is to pursue the quickest gains first, and use the increased intellectual effectiveness thus derived to help pursue successive gains. We see the quickest gains emerging from (1) giving the human the minute-by-minute services of a digital computer equipped with computer-driven cathode-ray-tube display, and (2) developing the new methods of thinking and working that allow the human to capitalize upon the computer's help. By this same strategy, we recommend that an initial research effort develop a prototype system of this sort aimed at increasing human effectiveness in the task of computer programming.

To give the reader an initial orientation about what sort of thing this computer-aided working system might be, we include below a short description of a possible system of this sort. This illustrative example is not to be considered a description of the actual system that will emerge from the program. It is given only to show the general direction of the work, and is clothed in fiction only to make it easier to visualize.

Let us consider an "augmented" architect at work. He sits at a working station that has a visual display screen some three feet on a side; this is his working surface, and is controlled by a computer (his "clerk") with which he can

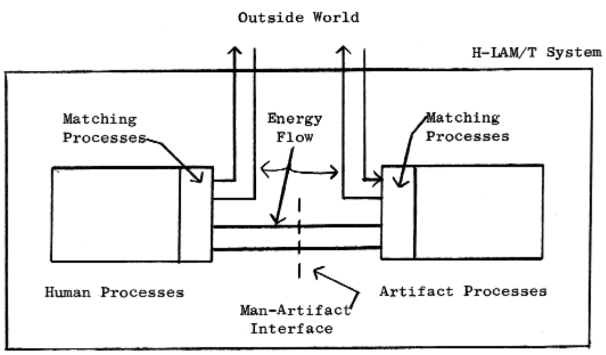

Figure 8.1. Portrayal of the Two Active Domains Within the H-LAM/T System.

From section II.C.3: The human and the artifacts are the only physical components of the H-LAM/T system. It is upon their capabilities that the ultimate capability of the system will depend. . . . There are thus two separate domains of activity within the H-LAM/T system: that represented by the human, in which all explicit-human processes occur; and that represented by the artifacts, in which all explicit-artifact processes occur. In any composite process, there is cooperative interaction between the two domains, requiring interchange of energy (much of it for information exchange purposes only). Figure 8.1 depicts this two-domain concept. . . .

Exchange across this [man-artifact] "interface" occurs when an explicit-human process is coupled to an explicit-artifact process. Quite often these coupled processes are designed for just this exchange purpose, to provide a functional match between other explicit-human and explicit-artifact processes buried within their respective domains that do the more significant things. For instance, the finger and hand motions (explicit-human processes) activate key-linkage motions in the typewriter (couple to explicit-artifact processes). But these are only part of the matching processes between the deeper human processes that direct a given word to be typed and the deeper artifact processes that actually imprint the ink marks on the paper.

communicate by means of a small keyboard and various other devices.

He is designing a building. He has already dreamed up several basic layouts and structural forms, and is trying them out on the screen. The surveying data for the layout he is working on now have already been entered, and he has just coaxed the "clerk" to show him a perspective view of the steep hillside building site with the roadway above, symbolic representations of the various trees that are to remain on the lot, and the service tie points for the different utilities. The view occupies the left two-thirds of the screen. With a "pointer," he indicates two points of interest, moves his left hand rapidly over the keyboard, and the distance and elevation between the points indicated appear on the right-hand third of the screen.

Now he enters a reference line with his "pointer," and the keyboard. Gradually the screen begins to show the work he is doing—a neat excavation appears in the hillside, revises itself slightly, and revises itself again. After a moment, the architect changes the scene on the screen to an overhead plan view of the site, still showing the excavation. A few minutes of study, and he enters on the keyboard a list of items, checking each one as it appears on the screen, to be studied later.

Ignoring the representation on the display, the architect next begins to enter a series of specifications and data—a six-inch slab floor, twelve-inch concrete walls eight feet high within the excavation, and so on. When he has finished, the revised scene appears on the screen. A structure is taking shape. He examines it, adjusts it, pauses long enough to ask for handbook or catalog information from the "clerk" at various points, and readjusts accordingly. He often recalls from the "clerk" his working lists of specifications and considerations to refer to them, modify them, or add to them. These lists grow into an ever-more-detailed, interlinked structure, which represents the maturing thought behind the actual design.

Prescribing different planes here and there, curved surfaces occasionally, and moving the whole structure about five feet, he finally has the rough external form of the building balanced nicely with the setting and he is assured that this

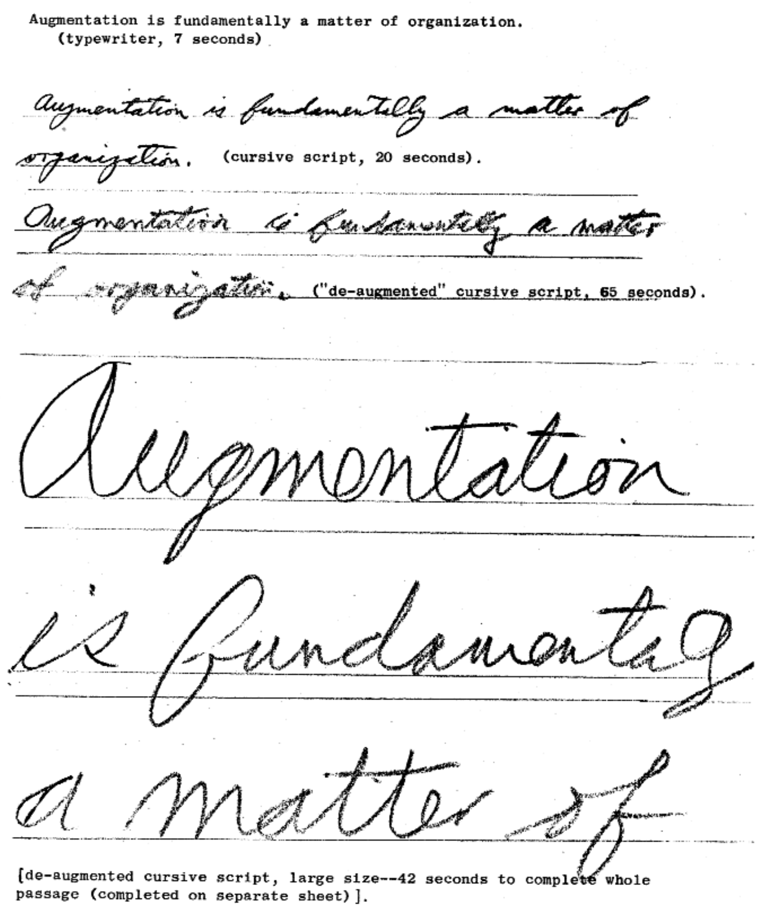

Figure 8.2. Experimental Results of Tying a Brick to a Pencil to "De-Augment" the Individual

From section II.C.4: Brains of equal power to ours could have evolved in an environment where the combination of artifact materials and muscle strengths were so scaled that the neatest scribing tool (equivalent to a pencil) possible had a shape and mass as manageable as a brick would be to us—assuming that our muscles were not specially conditioned to deal with it. We fastened a pencil to a brick and experimented. Figure 8.2 shows the results, compared with typewriting and ordinary pencil writing. . . . How would our civilization have matured if this had been the only manual means for us to use in graphical manipulation of symbols? For one thing, the record keeping that enables the organization commerce and government would probably have taken a form so different from what we know that our social structure would undoubtably have evolved differently. . . .

form is basically compatible with the materials to be used as well as with the function of the building.

Now he begins to enter detailed information about the interior. Here the capability of the "clerk" to show him any view he wants to examine (a slice of the interior, or how the structure would look from the roadway above) is important. He enters particular fixture designs, and examines them in a particular room. He checks to make sure that sun glare from the windows will not blind a driver on the roadway, and the "clerk" computes the information that one window will reflect strongly onto the roadway between 6 and 6:30 on midsummer mornings.

Next he begins a functional analysis. He has a list of the people who will occupy this building, and the daily sequences of their activities. The "clerk" allows him to follow each in turn, examining how doors swing, where special lighting might be needed. Finally he has the "clerk" combine all of these sequences of activity to indicate spots where traffic is heavy in the building, or where congestion might occur, and to determine what the severest drain on the utilities is likely to be.

All of this information (the building design and its associated "thought structure") can be stored on a tape to represent the "design manual" for the building. Loading this tape into his own "clerk," another architect, a builder, or the client can maneuver within this "design manual" to pursue whatever details or insights are of interest to him—and can append special notes that are integrated into the "design manual" for his own or someone else's later benefit.

In such a future working relationship between human problem-solver and computer "clerk," the capability of the computer for executing mathematical processes would be used whenever it was needed. However, the computer has many other capabilities for manipulating and displaying information that can be of significant benefit to the human in nonmathematical processes of planning, organizing, studying, etc. Every person who does his thinking with symbolized concepts (whether in the form of the English language, pictographs, formal logic, or mathematics) should be able to benefit significantly.

B Objective of the Study

The objective of this study is to develop a conceptual framework within which could grow a coordinated research and development program whose goals would be the following: (1) to find the factors that limit the effectiveness of the individual's basic information-handling capabilities in meeting the various needs of society for problem solving in its most general sense; and (2) to develop new techniques, procedures, and systems that will better match these basic capabilities to the needs, problems, and progress of society. We have placed the following specifications on this framework:

> (1) That it provide perspective for both long-range basic research and research that will yield practical results soon.
>
> (2) That it indicate what this augmentation will actually involve in the way of changes in working environment, in thinking, in skills, and in methods of working.
>
> (3) That it be a basis for evaluating the possible relevance of work and knowledge from existing fields and for assimilating whatever is relevant.
>
> (4) That it reveal areas where research is possible and ways to assess the research, be a basis for choosing starting points, and indicate how to develop appropriate methodologies for the needed research.

Two points need emphasis here. First, although a conceptual framework has been constructed, it is still rudimentary. Further search, and actual research, are needed for the evolution of the framework. Second, even if our conceptual framework did provide an accurate and complete basic analysis of the system from which stems a human's intellectual effectiveness, the explicit nature of future improved systems would be highly affected by (expected) changes in our technology or in our understanding of the human being.

. . .

III Examples and Discussion

A Background

2 Comments Related to [Vannevar] Bush's Article

There are many significant items in the article, but the main ones upon which we shall comment here will be those relative to the use and implications of his Memex. The associative trails whose establishment and use within the files he describes at some length provide a beautiful example of a new capability in symbol structuring that derives from new artifact-process capability, and that provides new ways to develop and portray concept structures. Any file is a symbol structure whose purpose is to represent a variety of concepts and concept structures in a way that makes them maximally available and useful to the needs of the human's mental-structure development—within the limits imposed by the capability of the artifacts and human for jointly executing processes of symbol-structure manipulation. The Memex allows a human user to do more conveniently (less energy, more quickly) what he could have done with relatively ordinary photographic equipment and filing systems, but he would have had to spend so much time in the lower-level processes of manipulation that his mental time constants of memory and patience would have rendered the system unusable in the detailed and intimate sense which Bush illustrates.

The Memex adds a factor of speed and convenience to ordinary filing-system (symbol-structuring) processes that would encourage new methods of work by the user, and it also adds speed and convenience for processes not generally used before. Making it easy to establish and follow the associative trails makes practical a new symbol-structuring process whose use can make a significant difference in the concept structuring and basic methods of work. It is also probable that clever usage of associative-trail manipulation can augment the human's process structuring and executing capabilities so that he could successfully make use of even more powerful symbol-structure manipulation processes utilizing the Memex capabilities. An example of this general sort of thing was given by Bush where he points out that the file index can be called to view at the push of a button, which implicitly provides greater capability to work within more sophisticated and complex indexing systems.

Note, too, the implications extending from Bush's mention of one user duplicating a trail (a portion of his structure) and giving it to a friend who can put it into his Memex and integrate it into his own trail (structure). Also note the "wholly new forms of encyclopedia," the profession of "trail blazers," and the inheritance from a master including "the entire scaffolding" by which such additions to the world's record were erected. These illustrate the types of changes in the ways in which people can cooperate intellectually that can emerge from the augmentation of the individuals. This type of change represents a very significant part of the potential value in pursuing research directly on the means for making individuals intellectually more effective

3 Some Possibilities with Cards and Relatively Simple Equipment

A number of useful new structuring processes can be made available to an individual through development and use of relatively simple equipment that is mostly electromechanical in nature and relatively cheap. We can begin developing examples of this by describing the hand-operated, edge-notched card system that I developed and used over the past eight years.

a An Existing Note and File System

The "unit records" here, unlike those in the Memex example, are generally scraps of typed or handwritten text on IBM-card-sized edge-notchable cards. These represent little "kernels" of data, thought, fact, consideration, concepts, ideas, worries, etc., that are relevant to a given problem area in my professional life. Each such specific problem area has its notecards kept in a separate deck, and for each such deck there is a master card with descriptors associated with individual holes about the periphery of the card. There is a field of holes reserved for notch coding the serial number of a reference from which the note on a card may have been taken, or the serial number corresponding to an individual from whom the information came directly (including a code for myself, for self-generated thoughts).

None of the principles of indexing or sorting used here is new: coordinate-indexing descriptors with direct coding on edge-notched cards, with needle-sort retrieval. Mainly what is new is the use of the smaller units of information, in restricted-subject sets (notedecks) so that I gain considerable flexibility in the manipulations of my thought products at the level at which I actually work in my minute-by-minute struggle with analytical and formulative thought. Not only do my own thoughts produce results in this fashion, but when I digest the writings of another person, I find generally anyway that I have extracted from his structure and integrated into my own a specific selection of facts, considerations, ideas, etc. Often these different extracted items fit into different places in my structure, or become encased in special substructures as I modify or expand his concepts. Extracting such items or kernels and putting each on its own notecard helps this process considerably—the role or position of each such item in the growth of the note structure is independent, and yet if desired all can quickly be isolated and extracted by simple needle sorting on the reference-number notching field.

These notecards represent much more than just an in formation file. They provide a workspace for me, in which I can browse, make additions or corrections, or build new sets of thought kernels with a good deal of freedom. I can leave notes with suggestions or questions for myself that will drop out at an appropriate later time. I can do document-reference searches with good efficiency, too, by needle sorting for notes within relevant descriptor categories. Any notecard with relevant notes on it points to the original source (by the source serial number, which I always write, together with the page, at the top of the card). When I am in the process of developing an integrated writeup covering some or all of the notedeck's material, I can quickly needle out a set of cards relevant to the topic under consideration at the moment—with all other cards in one pile to the side—and I need do a very minimum of hand searching or stacking in special little category piles. If I utilize specific information from another person, I can register my acknowledgment in my draft writeup merely by writing in the source serial number that is at the top of the notecard—it is a straightforward clerical job for a secretary later to arrange footnote entries and numbering.

b Comments on the System

First, let me relate what has been described to the special terms brought out in previous sections. The writing contained on each notecard is a small-sized symbol structure, representing or portraying to me a small structure of concepts. The notches on the edges of the cards are symbols that serve to tie these card-sized symbol substructures into a large symbol structure (the notedeck). One aspect of the structure is the physical grouping of the cards at a given time—which happens to be the only aspect of the over-all structuring that my human capabilities can make direct use of—and in this respect I can execute processes which produce restructuring (that is, physical regrouping) that helps me considerably to perceive and assimilate the concepts of worth to me. This restructuring is effected by composite processes involving me, a master code card, a sorting needle, and a work surface. I can add to the symbol structure by executing other composite processes which involve me, writing instruments (pen, pencil, or typewriter), a master code card, and a card notcher.

If my mental processes were more powerful, I could dispense with the cards, and hold all of the card-sized concept structures in my memory, where also would be held the categorization linkages that evolved as I worked (with my feet up on the artifacts and my eyes closed). As it is, and as it probably always will be no matter how we develop or train our mental capabilities, I want to work in problem areas where the number and interrelationship complexity of the individual factors involved are too much for me to hold and manipulate within my mind. So, my mind develops conscious sets of concepts, or recognizes and selects them from what it perceives in the work of others, and it directs the organization of an external symbol structure in which can be held and portrayed to the mind those concepts I cannot (reliably) remember or whose manipulations I cannot visualize. The price I pay for this "augmentation" shows up in the time and energy involved in manipulating artifacts to manipulate symbols to give me this artificial memory and visualization of concepts and their manipulation.

c Associative-Linking Possibilities

But let us go further with discussing specific examples of means for augmenting our intellects. In using the edge-notched-card system described, I found several types of structuring which that system could not provide, but which would both be very useful and probably obtainable with reasonably practical artifact means. One need arose quite commonly as trains of thought would develop on a growing series of notecards. There was no convenient way to link these cards together so that the train of thought could later be recalled by extracting the ordered series of notecards. An associative-trail scheme similar to that out lined by Bush for his Memex could conceivably be implemented with these cards to meet this need and add a valuable new symbol-structuring process to the system. Straightforward engineering development could provide a mechanism that would be able to select a specific card from a relatively large deck by a parallel edge-notch sort on a unique serial number notched into each card, and the search mechanism could be set up automatically by a hole sensing mechanism from internal punches on another card that was placed in the sensing slot. An auxiliary notching mechanism could automatically give succeeding serial-number encoding to new notecards as they are made up.

Suppose that one wants to link Card B to Card A, to make a trail from A to B. He puts Card B into a slot so that the edge-notched coding of the card's serial number can automatically be sensed, and slips Card A under a hole-punching head which duplicates the serial-number code of Card B in the coding of the holes punched in a specific zone on Card A. Later, when he may have discovered Card A, and wishes to follow this particular associative trail to the next card, he aligns that zone on Card A under a hole-sensing head which reads the serial number for Card B therein and automatically sets up the sorting mechanism. A very quick and simple human process thus initiates the automatic extraction of the next item on the associative trail. It's not unreasonable to assume that establishing a link would take about three seconds, and tracing a link to the next card about three to five seconds.

There would still be descriptor-code notching and selection to provide for general grouping classifications—and we can see that the system could really provide a means for *working within* the structure of the contained information.

d An Experiment Illustrating Usage and Further System Possibilities

I once tried to use my cards, with their separate little "concept packets," in the process of developing a file memo outlining the status and plans of a research project. I first developed a set of cards upon each of which I described a separate consideration, possibility, or specification about the memo—in the disorderly sequence in which they occurred to me as my thoughts about the basic features of the memo evolved. Right off the bat I noticed that there were two distinct groups—some ideas were about what the memo ought to accomplish, what time period it should cover, when it should be finished, what level and style of presentation should be used, etc., and some ideas were about the subject of the memo. As more thoughts developed, I found that the latter group also divided into ideas representing possible content and those representing possible organization.

I separated the cards into three corresponding groups (which I shall call Specification, Organization, and Content), and began to organize each of them. I started with the Specification group (it being the "highest" in nature), and immediately found that there were several types of notes within that group just as there had been in the total group. Becoming immediately suspicious, I sorted through each of the other two main groups and found similar situations in each. In each group there was finally to emerge a definite set of statements (product statements) that represented that group's purpose—e.g., the specifications currently accepted for the design of the memo—and some of the cards contained candidate material for this. But there were also considerations about what these final statements might include or exclude or take into account, or conditions under which inclusion or modification might be relevant, or statements that were too bulky or brief or imprecise to be used as final statements.

It became apparent that the final issuance from my work, the memo itself, would represent but one facet of a complex symbol structure that would grow as the work progressed—a structure comprising three main substructures, each of which had definite substructuring of its own that was apparent. I realized that I was being rather philosophically introspective with all of this analysis, but I was curious as to the potential value of future augmentation means in allowing me to deal explicitly with these types of structuring. So I went ahead, keeping the groups and sub-groups of cards separated, and trying to organize and develop them.

I found rather quickly that the job of extracting, rearranging, editing, and copying new statements into the cards which were to represent the current set of product statements in each grouping was rather tedious. This brought me to appreciate the value of some sort of copying device with which I could transfer specified strings of words from one card to another, thus composing new statements from fragments of existing ones. This type of device should not be too hard to develop and produce for a price that a professional man could justify paying, and it would certainly facilitate some valuable symbol-structuring processes.

I also found that there would have been great value in having available the associative-trail marking and following processes. Statements very often had implicit linkages to other statements in the same group, and it would have been very useful to keep track of these associations. For instance, when several consideration statements bore upon a given product statement, and when that product statement came to be modified through some other consideration, it was not always easy to remember why it had been established as it had. Being able to fish out the other considerations linked to that statement would have helped considerably.

Also, trial organizations of the statements in a group could be linked into trial associative trails, so that a number of such organizations could be constructed and considered without copying that many sets of specially ordered statements. Any of the previously considered organizations could be reconstructed at will.

In trying to do flexible structuring and restructuring within my experiment, I found that I just didn't have the means to keep track of all of the kernel statements (cards) and the various relationships between them that were important—at least by means that were easy enough to leave time and thought capacity enough for me to keep in mind the essential nature of the memo-writing process. But it was a very provocative experience, considering the possibilities that I sensed for the flexible and powerful ways in which I could apply myself to so universal a design task if I but had the necessary means with which to manipulate symbol structures.

It would actually seem quite feasible to develop a unit-record system around cards and mechanical sorting, with automatic trail-establishment and trail-following facility, and with associated means for selective copying or data transfer, that would enable development of some very powerful methodology for everyday intellectual work. It is plain that even if the equipment (artifacts) appeared on the market tomorrow, a good deal of empirical research would be needed to develop a methodology that would capitalize upon the artifact process capabilities. New concepts need to be conceived and tested relative to the way the "thought kernels" could be knitted together into working structures, and relative to the conceptual presentations which become available and the symbol-manipulation processes which provide these presentations. "Such an approach would present useful and interesting research problems, and could very likely produce practical and significant results (language, artifacts, methodology) for improving the effectiveness of professional problem solvers. However, the technological trends of today foretell the obsolescence of such electromechanical information-handling equipment." Very likely, by the time good augmentation systems could be developed, and the first groups of users began to prove them out so that they could gain more widespread acceptance, electronic data-processing equipment would have evolved much further and become much more prevalent throughout the critical-problem domains of our society where such ideas would first be adopted. The relative limitations of the mechanical equipment in providing processes which could be usefully integrated into the system would soon lead to its replacement by electronic computer equipment.

The next set of descriptive examples will involve the use of electronic computers, and their greatly increased flexibility and processing potential will be evident. Research based upon such electronic artifacts would be able to explore language and methodology innovations of a much wider range of sophistication than could research based upon limited and relatively inflexible electromechanical artifacts. In particular, the electronic-based experimental program could simulate the types of processes available from electromechanical artifacts, if it seemed possible (from the vantage of experience with the wide range of augmentation processes) that relatively powerful augmentation systems could be based upon their capabilities—but the relative payoffs for providing even-more-sophisticated artifact capabilities could be assessed too so that considerations of how much to invest in capital equipment versus how much increase in human effectiveness to expect could be based upon some experimental data.

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III Examples and Discussion

B Hypothetical Description of Computer-Based Augmentation System

4 Structuring an Argument

"If we want to go on to a higher-level capability to give you a feeling for how our rebuilt capability hierarchy works, it will speed us along to look at how we might organize these more primitive capabilities which I have demonstrated into some new and better ways to set up what we can call an 'argument.' This refers loosely to any set of statements (we'll call them 'product statements') that represents the product of a period of work toward a given objective. Confused? Well, take the simple case where an argument leads to a single product statement. For instance, you come to a particular point in your work where you have to decide what to do for the next step. You go through some reasoning process—usually involving statements—and come up with a statement specifying that next step. That final statement is the product statement, and it represents the product of the argument or reasoning process which led to it.

"You usually think of an argument as a serial sequence of steps of reason, beginning with known facts, assumptions, etc., and progressing toward a conclusion. Well, we do have to think through these steps serially, and we usually do list the steps serially when we write them out because that is pretty much the way our papers and books have to present them—they are pretty limiting in the symbol structuring they enable us to use. Have you even seen a 'scrambled-text' programmed instruction book? That is an interesting example of a deviation from straight serial presentation of steps.

"Conceptually speaking, however, an argument is not a serial affair. It is sequential, I grant you, because some statements have to follow others, but this doesn't imply that its nature is necessarily serial. We usually string Statement B after Statement A, with Statements C, D, E, F, and so on following in that order—this is a serial structuring of our symbols. Perhaps each statement logically followed from all those which preceded it on the serial list, and if so, then the conceptual structuring would also be serial in nature, and it would be nicely matched for us by the symbol structuring.

"But a more typical case might find A to be an independent statement, B dependent upon A, C and D independent, E depending upon D and B, E dependent upon C, and F dependent upon A, D, and E. See, sequential but not serial? A conceptual network but not a conceptual chain. The old paper and pencil methods of manipulating symbols just weren't very adaptable to making and using symbol structures to match the ways we make and use conceptual structures. With the new symbol-manipulating methods here, we have terrific flexibility for matching the two, and boy, it really pays off in the way you can tie into your work."

This makes you recall dimly the generalizations you had heard previously about process structuring limiting symbol structuring, symbol structuring limiting concept structuring, and concept structuring limiting mental structuring. You nod cautiously, in hopes that he will proceed in some way that will tie this kind of talk to something from which you can get the "feel" of what it is all about. As it turns out, that is just what he intends to do.

"Let's actually work some examples. You help me." And you become involved in a truly fascinating game. Joe tells you that you are to develop an argument leading to statements summarizing the augmentation means so far revealed to you for doing the kind of straight-text work usually done with a pencil and eraser on a single sheet of paper. You unconsciously look for a scratch pad before you realize that he is telling you that you are going to do this the "augmented way" by using him and his system—with artful coaching from him. Under a bit of urging from him, you begin self-consciously to mumble some inane statements about what you have seen, what they imply, what your doubts and reservations are, etc. He mercilessly ignores your obvious discomfort and gives you no cue to stop, until he drops his hands to his lap after he has filled five frames with these statements (the surplus filled frames disappeared to somewhere—you assume Joe knows where they went and how to get them back).

"You notice how you wandered down different short paths, and criss-crossed yourself a few times?" You nod—depressed, no defense. But he isn't needling you. "Very natural development, just the way we humans always seem to start out on a task for which we aren't all primed with knowledge, method, experience, and confidence—which is to include essentially every problem of any consequence to us. So let's see how we can accommodate the human's way of developing his comprehension and his final problem solution.

"Perhaps I should have stopped sooner—I *am* supposed to be coaching you instead of teasing you—but I had a reason. You haven't been making use of the simple symbol-manipulation means that I showed you—other than the shorthand for getting the stuff on the screens. You started out pretty much the way you might with your typewriter or pencil. I'll show you how you could have been doing otherwise, but I want you to notice first how hard it is for a person to realize how really unquestioning he is about the way he does things. Somehow we implicitly view most all of our methods as just sort of 'the way things are done, that's all.' You knew that some exotic techniques were going to be applied, and you'll have to admit that you were passively waiting for them to be handed to you."

With a non-committal nod, you suggest getting on with it. Joe begins, "You're probably waiting for something impressive. What I'm trying to prime you for, though, is the realization that the impressive new tricks *all* are based upon lots of changes in the little things you do. This computerized system is used over and over and over again to help me do little things—where my methods and ways of handling *little* things are changed until, lo, they've added up and suddenly I can do *impressive* new things."

You don't know. He's a nice enough guy, but he sure gets preachy. But the good side of your character shows through, and you realize that everything so far *has* been about little things—this is probably an important point. You'll stick with him. Okay, so what could you have been doing to use the simple tricks he had shown you in a useful way? Joe picks up the light pen, poises his other hand over the keyset, and looks at you. You didn't need the hint, but thanks anyway, and let's start rearranging and cleaning up the work space instead of just dumping more raw material on it.

With closer coaching now from Joe, you start through the list of statements you've made and begin to edit, re-word, compile, and delete. It's fun—"put that sentence back up here between these two"—and blink, it's done. "Group these four statements, indented two spaces, under the heading 'shorthand,'" and blinko, it's done. "Insert what I say next there, after that sentence." You dictate a sentence to extend a thought that is developing, and Joe effortlessly converts it into an inserted new sentence. Your ideas begin to take shape, and you can continually re-work the existing set of statements to keep representing the state of your "concept structure."

You are quite elated by this freedom to juggle the record of your thoughts, and by the way this freedom allows you to *work* them into shape. You reflected that this flexible cut-and-try process really did appear to match the way you seemed to develop your thoughts. Golly, you could be writing math expressions, ad copy, or a poem, with the same type of

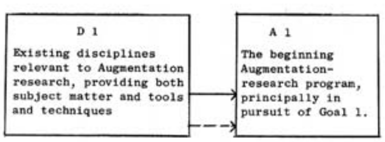

Figure 8.3. Initial Augmentation-Research Program

From section IV.E: An integrated set of tools and techniques will represent an art of doing augmentation research. Although no such art exists ready-made for our use, there are many applicable or adaptable tools and techniques to be borrowed from other disciplines. Psychology, computer programming and physical technology, display technology, artificial intelligence, industrial engineering (e.g., motion and time study). management science, systems analysis, and information retrieval are some of the more likely sources. These disciplines also offer initial subject matter for the research. Because this kind of diagramming can help more later on, we represent in Figure 8.3 the situation of the beginning research drawing upon existing disciplines for subject matter and tools and techniques.

The program begins with general dependence upon other, existing disciplines for its subject matter (solid arrow) and its tools and techniques (dashed arrow). Goal 1 has been stated as that of verifying the basic hypothesis that concerted augmentation research can increase the intellectual effectiveness of human problem solvers.

benefit. You were ready to tell Joe that now you saw what he had been trying to tell you about matching symbol structuring to concept structuring—when he moved on to show you a succession of other techniques that made you realize you hadn't yet gotten the full significance of his pitch.

"So far the structure that you have built with your symbols looks just like what you might build with pencil-and-paper techniques—only here the building is so much easier when you can trim, extend, insert, and rearrange so freely and rapidly. But the same computer here that gives us these freedoms with so trivial an application of its power, can just as easily give us other simple capabilities which we can apply to the development and use of different *types* of structure from what we used to use. But let me unfold these little computer tricks as we come to them.

"When you look at a given statement in the middle of your argument structure, there are a number of things you want to know. Let's simplify the situation by saying that you might ask three questions, 'What's this?', 'How come?', and 'So what?' Let's take these questions one at a time and see how some changes in structuring might help a person answer them better.

"You look at a statement and you want to understand its meaning. You are used to seeing a statement portrayed in just the manner you might hear it—as a serial succession of words. But, just as with the statements within an argument, the conceptual relationship among the words of a sentence is not generally serial, and we can benefit in matching better to the conceptual structure if we can conveniently work with certain non-serial symbol-structuring forms within sentences.

"Most of the structuring forms I'll show you stem from the simple capability of being able to establish arbitrary linkages between different substructures, and of directing the computer subsequently to display a set of linked substructures with any relative positioning we might designate among the different substructures. You can designate as many different kinds of links as you wish, so that you can specify different display or manipulative treatment for the different types."

Joe picked out one of your sentences, and pushed the rest of the text a few lines up and down from it to isolate it. He then showed you how he could make a few strokes on the keyset to designate the type of link he wanted established, and pick the two symbol structures that were to be linked by means of the light pen. He said that most links possessed a direction, i.e., they were like an arrow pointing from one substructure to another, so that in setting up a link he must specify the two substructures in a given order.

He went to work for a moment, rapidly setting up links within your sentence. Then he showed you how you could get some help in looking at a statement and understanding it. "Here is one standard portrayal, for which I have established a computer process to do the structuring automatically on the basis of the interword links." A few strokes on the keyset and suddenly the sentence fell to pieces—different parts of it being positioned here and there, with some lines connecting them. "Remember diagramming sentences when you were studying grammar? Some good methods, plus a bit of practice, and you'd be surprised how much a diagrammatic breakdown can help you to scan a complex statement and untangle it quickly.

"We have developed quite a few more little schemes to help at the statement level. I don't want to tangle you up with too much detail, though. You can see, probably, that quick dictionary-lookup helps." He aimed at a term with the light pen and hit a few strokes on the keyset, and the old text jumped farther out of the way and the definition appeared above the diagram, with the defined term brighter than the rest of the diagram. And he showed you also how you could link secondary phrases (or sentences) to parts of the statement for more detailed description. These secondary substructures wouldn't appear when you normally viewed the statement, but could be brought in by simple request if you wanted closer study.

"It proves to be terrifically useful to be able to work easily with statements that represent more sophisticated and complex concepts. Sort of like being able to use structural members that are lighter and stronger—it gives you new freedom in building structures. But let's move on—we'll come back to this area later, if we have time.

"When you look at a statement and ask, 'How come?', you are used to scanning back over a serial array of previously made statements in search of an understanding of the basis upon which this statement was made. But some of these previous statements are much more significant than others to this search for understanding. Let us use what we call 'antecedent links' to point to these, and I'll give you a basic idea of how we structure an argument so that we can quickly track down the essential basis upon which a given statement rests."

You helped him pick out the primary antecedents of the statement you had been studying, and he established links to them. These statements were scattered back through the serial list of statements that you had assembled, and Joe showed you how you could either brighten or underline them to make them stand out to your eye—just by requesting the computer to do this for all direct antecedents of the designated statement. He told you, though, that you soon get so you aren't very much interested in seeing the serial listing of all of the statements, and he made another request of the computer (via the keyset) that eliminated all the prior statements, except the direct antecedents, from the screen. The subject statement went to the bottom of the frame, and the antecedent statements were neatly listed above it.

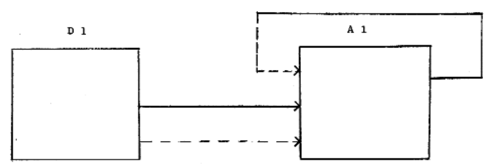

Figure 8.4. Regeneration

From section IV.F: We basically recommend A 1 research adhering to whatever formal methodology is required for (a) knowing when an improvement in effectiveness has been achieved, and (b) knowing how to assign *relative* value to the changes derived from two competing innovations.

Beyond this, and assuming dedication to this goal, reasonable maturity, and plenty of energy, intelligence, and imagination, we would recommend turning loose a group of four to six people (or a number of such groups) to develop means that augment their own programming capability. We would recommend that their work begin by developing the capability for composing and modifying simple symbol structures, in the manner pictured in Section III-B-2, and work up through a hierarchy of intermediate capabilities toward the single high-level capability that would encompass computer programming. This would allow their embryonic and free wheeling "art of doing augmentation research" to grow and work out its kinks through a succession of increasingly complex system problems—and also, redesigning a hierarchy from the bottom up somehow seems the best approach.

As for the type of programming to tell them to become good at—tell them, "the kind that you find you have to do in your research." In other words, their job assignment is to develop means that will make them more effective at doing their job. Figure 8.4 depicts this schematically, with the addition to what was shown in Figure 8.3 of a connection that feeds the subject-matter output of their research (augmentation means for their type of programming problems) right back into their activity as improved tools and techniques to use in their research.

Joe then had you designate an order of “importance to comprehension” among these statements, and he rearranged them accordingly as fast as you could choose them. (This choosing was remarkably helped by having only the remainder statements to study for each new choice—another little contribution to effectiveness, you thought.) He mentioned that you could designate orderings under several different criteria, and later have the display show whichever ordering you wished. This, he implied, could be used very effectively when you were building or studying an argument structure in which from time to time you wanted to strengthen your comprehension relative to different aspects of the situation.

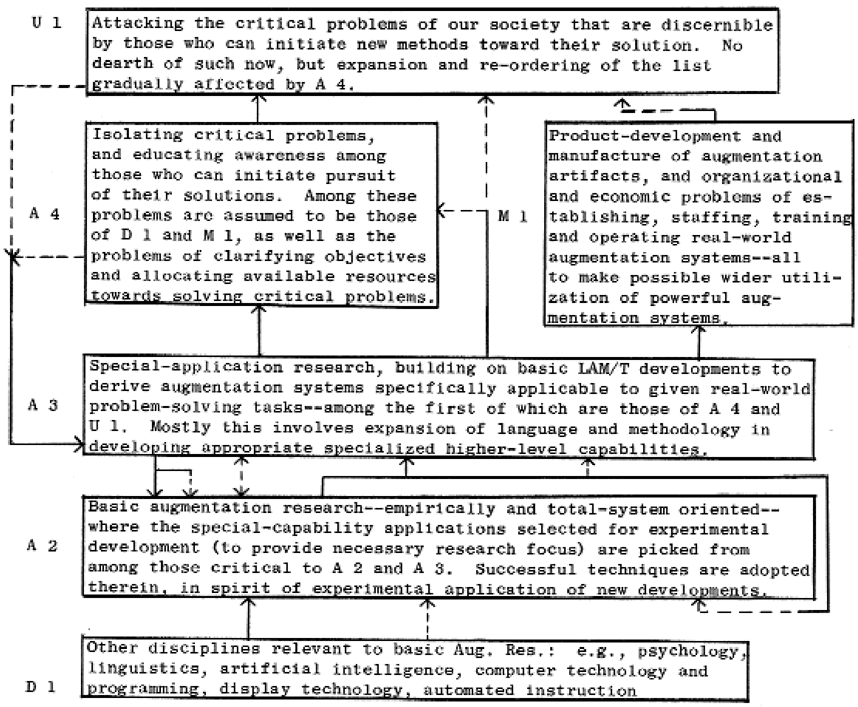

Figure 8.5. A Total Program

Suggested relationships among the major activities involved in achieving the stated objective (essentially, of significantly boosting human power in A 4 and U 1). Solid lines represent subject information or artifacts used or generated within an activity, and dashed lines represent special tools and techniques for doing the activity in the box to which they connect. Subject product of an activity (output solid) can be used as working material (input solid) or as tools and techniques (input dashed). Tools and techniques as used or needed in an activity (output dashed) can be used as either to work on (input solid) or as tools and techniques to work with (input dashed).

“Each primary antecedent can similarly be linked to its primary antecedents, and so on, until you arrive at the statements representing the premises, the accepted facts, and the objectives upon which this argument had been established. When we had established the antecedent links for all the statements in the argument, the question ‘So what?’ that you might ask when looking at a given statement would be answered by looking for the statements for which the given statement was an antecedent. We already have links to these consequents—just turn around the arrows on the antecedent links and we have consequent links. So we can easily call forth an uncluttered display of consequent statements to help us see why we needed this given statement in the argument.

“To help us get better comprehension of the structure of an argument, we can also call forth a schematic or graphical display. Once the antecedent-consequent links have been established, the computer can automatically construct such a display for us.” So, Joe spent a few minutes (with your help) establishing a reasonable set of links among the statements you had originally listed. Then another keyed-in request to the computer, and almost instantaneously there appeared a network of lines and dots that looked something like a tree—except that sometimes branches would fuse together. “Each node or dot represents one of the statements of your argument, and the lines are antecedent-consequent links. The antecedents of one statement always lie above that statement—or rather, their nodes lie above its node. When you get used to using a network representation like this, it really becomes a great help in getting the feel for the way all the different ideas and reasoning fit together—that is, for the conceptual structuring.”

Joe demonstrated some ways in which you could make use of the diagram to study the argument structure. Point to any node, give a couple of strokes on the keyset, and the corresponding statement would appear on the other screen—and that node would become brighter. Call the antecedents forth on the second screen, and select one of special interest—deleting the others. Follow back down the antecedent trail a little further, using one screen to look at the detail at any time, and the other to show you the larger view, with automatic node-brightening indication of where these detailed items fit in the larger view.

"For a little embellishment here, and to show off another little capability in my repertoire, let me label the nodes so that you can develop more association between the nodes and the statements in the argument. I can do this several ways. For one thing, I can tell the computer to number the statements in the order in which you originally had them listed, and have the labelling done automatically." This took him a total of five strokes on the keyset, and suddenly each node was made into a circle with a number in it. The statements that were on the second screen now each had its respective serial number sitting next to it in the left margin. "This helps you remember what the different nodes on the network display contain. We have also evolved some handy techniques for constructing abbreviation labels that help your memory quite a bit.

"Also, we can display extra fine-structure and labelling detail within the network in the specific local area we happen to be concentrating upon. This finer detail is washed out as we move to another spot with our close attention, and the coarser remaining structure is compressed, so that there is room for our new spot to be blown up. It is a lot like using zones of variable magnification as you scan the structure—higher magnification where you are inspecting detail, lower magnification in the surrounding field so that your feel for the whole structure and where you are in it can stay with you."

5 General Symbol Structuring

"If you are tangling with a problem of any size—whether it involves you for half an hour or two years—the entire collection of statements, sketches, computations, literature sources, and source extracts that is associated with your work would in our minds constitute a single symbol structure. There may be many levels of substructuring between the level of individual symbols and that represented by the entire collection. You and I have been working with some of the lower-ordered substructures—the individual statements and the multistatement arguments—and have skimmed through some of the ways to build and manipulate them. The results of small arguments are usually integrated in a higher level network of argument or concept development, and these into still higher-level networks, and so on. But at any such level, the manner in which the interrelationship between the kernels of argument can be tagged, portrayed, studied and manipulated is much the same as those which we have just been through.

"Substructures that might represent mathematical or formal-logic arguments may be linked right in with substructures composed of the more informal statements. Substructures that represent graphs, curves, engineering drawings, and other graphical forms can likewise be integrated. One can also append special substructures, of any size, to particular other substructures. A frequent use of this is to append descriptive material—something like footnotes, only much more flexible. Or, special messages can be hung on that offer ideas such as simplifying an argument or circumventing a blocked path—to be uncovered and considered at some later date. These different appended substructures can remain invisible to the worker until such time as he wants to flush them into view. He can ask for the cue symbols that indicate their presence (identifying where they are linked and what their respective types are) to be shown on the network display any time he wishes, and then call up whichever of them he wishes. If he is interested in only one type of appended substructure, he can request that only the cues associated with that type be displayed.

"You should also realize that a substructure doesn't have to be a hunk of data sitting neatly distinct within the normal form of the larger structure. One can choose from a symbol structure (or substructure, generally) any arbitrary collection of its substructures, designate any arbitrary structuring among these and any new substructures he wants to add, and thus define a new substructure which the computer can untangle from the larger structure and present to him at any time. The associative trails that Bush suggested represent a primitive example of this. A good deal of this type of activity is involved during the early, shifting development of some phase of work, as you saw when you were collecting tentative argument chains. But here again, we find ever more delightful ways to make use of the straightforward-seeming capabilities in developing new higher-level capabilities—which, of course, seem sort of straightforward by then, too.

"I found, when I learned to work with the structures and manipulation processes such as we have outlined, that I got rather impatient if I had to go back to dealing with the serial-statement structuring in books and journals, or other ordinary means of communicating with other workers. It is rather like having to project three-dimensional images onto two-dimensional frames and to work with them there instead of in their natural form. Actually, it is much closer to the truth to say that it is like trying to project n-dimensional forms (the concept structures, which we have seen can be related with many many nonintersecting links) onto a one-dimensional form (the serial string of symbols), where the human memory and visualization has to hold and picture the links and relationships. I guess that's a natural feeling, though. One gets impatient any time he is forced into a restricted or primitive mode of operation—except perhaps for recreational purposes.

"I'm sure that you've had the experience of working over a journal article to get comprehension and perhaps some special-purpose conclusions that you can integrate into your own work. Well, when you ever get handy at roaming over the type of symbol structure which we have been showing here, and you turn for this purpose to another person's work that is structured in this way, you will find a terrific difference there in the ease of gaining comprehension as to what he has done and why he has done it, and of isolating what you want to use and making sure of the conditions under which you can use it. This is true even if you find his structure left in the condition in which he has been working on it—that is, with no special provisions for helping an outsider find his way around. But we have learned quite a few simple tricks for leaving appended road signs, supplementary information, questions, and auxiliary links on our working structures—in such a manner that they never get in our way as we work—so that the visitor to our structure can gain his comprehension and isolate what he wants in marvelously short order. Some of these techniques are quite closely related to those used in automated-instruction programming—perhaps you know about 'teaching machines?'

"What we found ourselves doing, when having to do any extensive digesting of journal articles, was to type large batches of the text verbatim into computer store. It is so nice to be able to tear it apart, establish our own definitions and substitute, restructure, append notes, and so forth, in pursuit of comprehension, that it was generally well worth the trouble. The keyset shorthand made this reasonably practical. But the project now has an optical character reader that will convert our external references into machine code for us. The references are available for study in original serial form on our screens, but any structuring and tagging done by a previous reader, or ourselves, can also be utilized.

"A number of us here are using the augmented systems for our project research, and we find that after a few passes through a reference, we very rarely go back to it in its original form. It sits in the archives like an orange rind, with most of the real juice squeezed out. The contributions from these references form sturdy members of our structure, and are duly tagged as to source so that acknowledgment is always implicitly noted. The analysis and digestion that any of us makes on such a reference is fully available to the others. It is rather amazing how much superfluous verbiage is contained in those papers merely to try to make up for the pitifully sparse possibilities available for symbol structuring in printed text."

Reference

1. Kennedy, J. L. and Putt, G. H., "Administration of Research in a Research Corporation," RAND Corporation Report P-847 (20 April 1956).