The intelligence cycle—A differentiated perspective on information processing

by PETER G. W. KEEN
Stanford University
Stanford, California

ABSTRACT

This brief position paper presents a framework for mapping computer-based information aids onto the mental activities involved in the full problem-solving process. It argues that these activities are best described in terms of operators—the verbs and commands that the individual uses in a particular stage of the Intelligence Cycle.

The cycle begins with Discovery, the recognition of some signal requiring response. Discovery filters data into information and mainly involves operators that attenuate or amplify data: “alert,” “keep track of” (amplification) and “summarize,” “report averages” (attenuation). Few computer tools support amplification. The second stage, Interpretation is one where the machine generally outperforms the human mind, especially in inference and statistical analysis. Examples of operators for this stage are “compare,” “review” and “suggest.” The final stage, Analysis, is strongly supported by management science, especially through optimization models; typical operators are “test the impact of” and “evaluate.”

None of our current tools supports the full Intelligence cycle. The position paper suggests that the development of a science of information-processing must both identify the cognitive operators underlying the activities within the cycle and match the technical building blocks to them.

INTRODUCTION

Developments in information-processing are mainly driven by technology; new tools generate new uses. As relational data base or pattern recognition methodologies move from the laboratory to commercial availability, we will extend our ability to help Knowledge Workers make more effective and more efficient use of their information resources. This process is fragmented and relies on serendipity; it also obscures the broader concern:

What is the objective of the science of information-processing?
What are the activities its tools support and augment?

The aim of this presentation is to step back and map the technology into its context—the cycle of Intelligence, a process of Discovery, Interpretation and Analysis which begins from an initial awareness of a stimulus or problem and ends with a decision. By clarifying the operations within this cycle, we can both assess the techniques we now have and define the areas of most need and payoff. It is this analysis that should drive the technology and determine the tools we require.

The scheme presented here is a paradigm, a conceptual framework for organizing current knowledge, rather than a formal theory. It derives mainly from cognitive psychology, the science of human information-processing. Its emphasis is descriptive; before we can prescribe tools for improving an activity, we must first describe its dynamics and context. In general, our technical focus has stressed prescription at the expense of this understanding.

The paradigm clarifies some traditional distinctions in discussions of human response to and use of information:

- structured versus unstructured
- data versus information
- qualitative versus quantitative
- problem-finding versus problem-solving

The presentation is influenced by Miller’s definition of a psychology for man-machine systems; as here, he similarly focuses on the activity of information-processing, in terms of operators—verbs such as “show me,” “scan” and “summarize.” Tools can best be understood in relation to the operators they support.

THE CYCLE OF INTELLIGENCE

Most existing tools assist a Knowledge Worker who already has a purpose: a researcher scanning a database, an analyst reviewing a situation or a manager requesting summary reports. The Intelligence cycle begins well before this stage and includes Discovery—identifying and defining the problem and purpose. At an extreme, the Knowledge Worker sits daydreaming while the world around him randomly throws in his direction signal and noise. The cycle begins only when he is alerted to some signal.
Sometimes, the Discovery process is passive; he may not be actively scanning his environment. He may thus overlook "relevant" data.

Many commentators have emphasized that data becomes information by being filtered through some mental model that gives it meaning and relevance. The mind outperforms most computer-based tools in this process, which relies on alertness, pattern-creation and pattern-recognition. Of course, human limitations on memory, attention span and capacity for assimilating large masses of data make machine support invaluable in many instances.

Discovery filters data into information. In many ways it is the key stage in the cycle, in that it involves problem-finding. Once alerted to a signal, we can generally respond to it if only through some barely adequate rule of thumb or standard operating procedure, but we may easily overlook a potentially critical signal. If we can scan more alertly or provide better filters, we reduce the risk of doing so, but the effort needed may exceed our resources. It is thus desirable to automate part of the filter. What are the criteria for doing so? The technical focus does not itself define any criterion.

Stafford Beer, the British cybernetician, describes the filter in terms of attenuation and amplification. Discovery reduces chaos to singularity. Huge volumes of data are attenuated through summary, selection and aggregation. Key signals are amplified and drawn to our attention. In general we have many tools for attenuation—for reducing the load on our limited attention and capacity; most reporting systems organize mass data into "meaningful" summary. Beer gives an example of amplification in the CYBERSTRIDE system he helped build for the Chilean government. A forecasting algorithm, based on Bayesian decision theory, trims the stream of data on ongoing economic activity and tests if new signals imply a change in current trends and consequently a need to revise the mental model: if they do not the data is ignored and the Knowledge Worker not burdened with it. If the input implies a shift, the signal is amplified and the worker alerted to it.

The operators relevant to attenuation include "alert," "keep track of," and "locate any discrepancy." These are clearly different from "summarize" and "report averages," operators relating to attenuation. Information tools for Discovery thus need to be differentiated. We have far more tools for attenuation than for amplification; since the latter is central to problem-finding, this is clearly an area of great potential payoff in the selective development of new tools.

Attenuated information needs interpretation while amplification leads to Search, to a response to the signal and a more active effort at Discovery (see Figure 1). In either instance, only now is the worker aware of purpose and ready to select information and analytic aids. The second stage in the cycle, Interpretation, is largely inferential. The operators—the commands the worker gives to his tools—include "suggest," "review," "compare" and "deduce the (often statistical) meaning of." It is fairly easy to map techniques into this activity. Interactive Decision Support Systems such as Gerrity’s portfolio management system are explicitly designed in terms of such operators as "SCAN" and "HISTO" (provide histograms).

While man outperforms machine in most aspects of Discovery, he is much less effective in Interpretation. Tversky and Kahneman emphasize the frequency with which individuals make simple statistical errors. Edwards similarly points out our inability to make effective use of information we already have (to update probability estimates, for example). Tools such as MYCIN, which aids medical diagnosticians in the process of inference, exploit the machine’s comparative advantage in Interpretation.

The final stage of the cycle is Analysis, the assessment of interpreted information; this usually results in some conscious decision. Discovery is mainly perceptual and therefore hard to observe or make explicit but Analysis is generally conscious, methodological and sequential. It is concerned more with the use of information than information itself. Its operators include "evaluate," "compare these alternatives" and "test the impact of"—of course "what if." The tools of management science—optimization and simulation models—obviously support these. It is not clear where man outperforms machine or vice versa. Many problem-solvers prefer to rely on their own intuitive methods although in structured situations they will rely on formal models.

Because Analysis is conscious and sequential, it is often constrained by time and computational effort. In many cases, we simplify the problem to the point where it is feasible for us to handle its demands, even if this involves misrepresentation—and sometimes perversion. In many cases, by automating the operators it involves, we encourage the individual to make more comparisons, to enlarge his "bounded rationality;" a frequent benefit cited for interactive computer systems is simply that they allow a user to test out more alternatives. More is not necessarily the same as better; such support may thus improve efficiency but not effectiveness. In developing tools for Analysis, we must consider which operators they support and what "improvement" means (and is worth). Automatic mechanical aspects of Analysis (comparisons, summarization) loosen the bounds of rationality and potentially releases time for more attention to issues of effectiveness.

TOWARDS A DIFFERENTIATED PERSPECTIVE

The paradigm presented here can be expanded to give a fairly rigorous summary of both human information-processing activities and computer-based aids. The latter are the building blocks for a system to support the full cycle of intelligence. If we focus on the operators needed by the Knowledge Worker, we will define those blocks in a far more differentiated way than we do now. The issue is not simply for example, between qualitative and quantitative data or structured and unstructured problems. In the Discovery stage, attenuation generally involves numeric, and amplification judgmental, information. Our tools should reflect this.
The paradigm implies selective development of new techniques, matched to specific operators, rather than imposition of the methods on the overall cycle. Any catalog of existing tools will show an abundance of aids for Interpretation and Analysis and near absence of support for Discovery. Any detailed examination of the operators involved in Discovery will, as a corollary, suggest that retrieval methods suitable for scanning and directed search are of little value for amplification and alerting the Knowledge Worker.

There is not space in this position paper to explore the paradigm in detail. The following assertions summarize its intent:

1. None of our tools can support the full Intelligence cycle, nor should we assume that they are other than building blocks;
2. In developing information aids, we must look at the activities involved in the cycle and draw on descriptive
and psychological models;
3. Tools are best defined in relation to operators;
4. We do not yet have a science of information processing;
even if this paradigm is inaccurate or incomplete we need such frameworks that force us to develop a clearer sense of what our efforts should aim towards and what our techniques really are.

REFERENCES

2. More recently, the term "cognitive sciences" has been used by researchers to define a fusion between developmental psychology, Artificial Intelligence & information-processing theories.
17. See Reference 3, Chapter 1 for a discussion of the relevance of this distinction for the design of computer systems.