Book Reviews

The Memory System

Human Associative Memory. JOHN R. ANDERSON and GORDON H. BOWER. Winston, Washington, D.C., 1973 (distributor, Halsted [Wiley], New York). xvi, 524 pp., illus. $14.95. Experimental Psychology Series.

How does the mind progress from one idea to another? The 2000-year-old doctrine of association of ideas provides an answer based upon the existence of prior bonds laid down in memory by past events. The idea of associative bonds was not only seductively simple, but also had the virtue of fitting with popular views about connections in the nervous system. It is no wonder that the first systematic attempt to study human higher mental processes, in the late 19th century, was concerned with the growth and loss of associations. The overwhelming preponderance of studies of memory, despite frequent criticism of their artificiality, have been concerned with them.

During the last decade, however, associationism appeared to be submerged by the logical proof that no theory positing one-to-one connections between stimuli and responses could generate a grammar sufficiently complex to underlie human languages. Moreover, new questions about memory arose, from work in artificial intelligence, to which associational theories were inadequate; even if correct, they seemed unable to help us understand human ability to retrieve information, in response to specific queries.

Nevertheless, it is clear that habitual associations often intrude and guide our thoughts even when quite inappropriate to the task. Anderson and Bower present the first book-length treatment of attempts to produce a theory of human memory which is consistent with evidence for associational processes but replaces traditional connectionism with hierarchical memory structures reflecting propositions abstracted from input. They try to show how their memory system can illuminate the understanding of encoding, retrieval, and retention of meaningful information in a variety of task environments.

The book consists of three parts. The first five chapters provide a general setting by tracing the history and current status of associationism and of the rationalist opposition to it. The history is useful, but the authors' effort to identify their theory as associational is not convincing. What most relates the theory to associationism is the assumption that the memory system is not strategy dependent and operates in the same way regardless of task demands. This is an important assumption which warrants more direct tests than are provided in the book. But even if it is correct, another part of their theory—that the memory system is interfaced to other processes that are strategy dependent—suggests that performance as a whole might only weakly reflect associational bonds.

The second part of the book, chapters 6 through 9, outlines the model of human associative memory (HAM). The authors have programmed portions of HAM for the computer, but they insist it is not the program but the general assumptions behind it that represent their information-processing theory of human memory. They freely admit that more efficient simulations exist for doing the things the HAM program does, but argue that it is better designed to lay bare the psychological processes of interest.

The basic idea of HAM is to provide a deep structure sufficient to code and retrieve propositions. Between the external world and the associative memory lies a parser which converts input of any type into the propositional form appropriate for HAM. As in most psychological theories, one can get the idea of the theoretical position by examining the authors' prototypical example, in this case a sentence of the form "In the park a hippie touched a debutante." To encode this sentence, HAM produces a binary tree. The first binary decision separates the context consisting of the place (park) and time (past) of the proposition from the fact asserted by the proposition. The fact is further divided into a subject (hippie) and an object (debutante) connected by a relationship (touched). Unlike traditional associational models, HAM builds the notion of different types of relationships directly into the memory system and depends upon them to direct retrieval. Such propositions are linked together to form more complex hierarchical structures. These hierarchical structures are the internal representation of past experience. The authors argue that the structure of HAM is designed to encode any input, not just language. They present material to show that visual scenes are stored in propositional form. In my view they do not make a case that encodings of visual scenes are propositional, and it seems still less likely that our motor skills are stored as propositions in the HAM sense.

Chapter 9 outlines the way in which information is retrieved from HAM when questions are asked. The encoding of the input message (say, Did a man touch a debutante?) is followed by a parallel search of the memory system starting with each terminal node of the tree representing the input string (man, debutante). Once the correct memory node is located, associations to that node which reflect the proper relationship are searched serially. Although much of the system remains to be programmed successfully, the assumptions are of particular interest because a large number of psychological experiments have been performed that can be embedded in the framework provided by Anderson and Bower. For example, experiments have forced a hybrid model of serial and parallel processes; HAM suggests, as does the empirical literature, that search among links to a particular node tends to be serial, since search time increases with the number of links, while distinct memory nodes may be searched simultaneously without interference.

The scheme developed to code propositions into HAM has many inherent limitations. For example, in parsing material from the world the representational structure of HAM is not available,

so the parser must be assumed to operate blindly, an assumption that violates empirical data as well as limits the complexity of the simulation. The authors clearly recognize these limitations, and take what seems to me to be a reasonable view toward them. Rather than further complicate their system, they propose to take their model into the domain of empirical tests and determine in what way it succeeds in illuminating data.

Part 3 of the book consists of six chapters in which HAM is applied to a large variety of problems that have been developed in current experimental psychology: sentence learning, linguistic abstraction, retrieval of facts, answering questions, strategies of rote learning, and interference in forgetting. These six chapters constitute in themselves a fascinating review of the current state of the field and provide a number of new experiments. They justify the author's view that HAM can serve to generate new ideas and relate scattered findings in what appear to be very different areas. As an example of their approach one may take HAM's account of the interference theory of forgetting. The basis of this theory is the finding that the ability to recall an associative relationship between two items A and B will be suppressed if the subject learns a new association between A and C. According to HAM, such interference is the by-product of its effort to avoid indefinitely long searches for particular items. Consequently the authors argue that "the acquisition of new associations will tend to bury old associations and make them inaccessible whenever the list is searched." It is apparent that interference in forgetting must be related to the abstractive nature of human memory. The suggestion that interference in recall is tied to retrieval rules which prevent long search loops is an example of the type of hypothesis that can be achieved from a general model of memory.

Human Associative Memory should serve to impel experimentation toward important areas and should also provide a heuristic representation for the empirical results so far obtained. Whether or not our memories are HAM-like, the next generation of memory researchers will need to have a representation like HAM in their memories.

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Semiconductor Physics

Deep Impurities in Semiconductors. A. G. MILNES. Wiley-Interscience, New York, 1973. xviii, 526 pp., illus. $24.95.

Impurity levels in a semiconductor may exist anywhere within the energy gap between the valence and conduction bands. Deep levels, those far from the band edges, are caused primarily by substitutional impurities that differ greatly from the host atoms and by lattice vacancies. Interest in deep levels is rapidly increasing as other aspects of semiconductor physics more closely associated with the perfect crystal, such as energy band structure, carrier transport, and excitons and shallow impurities, are becoming well understood.

Deep impurities have been used in the fabrication of light-emitting diodes and switching transistors, but they are even more important to technology because of their deleterious effects. Deep impurities cause nonradiative electron-hole recombination. Consequently they are thought to be at least partially responsible for limiting the efficiency of light-emitting semiconductor devices and causing their degradation.

Despite their recognized importance, deep impurities are poorly understood. For example, the levels associated with lattice vacancies in III-V compounds are not yet known and the mechanism whereby carriers lose their energy when they are captured by deep impurities are for the most part not known even for well-studied impurities such as gold in silicon. A major problem in this field has been the lack of sensitive and convenient techniques for detecting deep levels and measuring their properties unambiguously. Suitable techniques based on junction capacitance measurements are only now becoming available.

The author's approach in reviewing this old but poorly understood field is to discuss briefly many aspects of the subject while extensively citing the vast and widely scattered literature. To limit the size of his book he has excluded II-IV semiconductors and deep levels introduced by radiation damage. He begins by cataloging the energy levels of deep impurities observed in silicon, germanium, and III-V compounds. This is followed by a discussion of the statistics and the kinetics of carriers in the presence of deep traps and recombination centers. He then discusses the wide variety of electrical measurements that have been used to determine properties of deep impurities, including photoconductivity, capacitance, and thermally stimulated current measurements. The final section of the book treats a variety of transport phenomena involving traps, including current flow due to double injection and domains and oscillations caused by field enhanced capture of carriers.

Students and researchers interested in deep impurities will find this book valuable as a summary of factual material and as an up-to-date guide to the literature. It is well indexed and contains a bibliography of 1894 references, including some 1973 papers. Little space is devoted to theoretical foundations or to drawing general conclusions. This is appropriate, since a broad understanding of many aspects of deep impurities is yet to come.

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Gravimetry

Theory of the Earth's Gravity Field. MILOŠ PICK, JAN PÍCHA, and VINCENC VYSKOČIL. Elsevier, New York, 1973. 538 pp., illus. $34.

This book is what it says, an exposition of the theory of the earth's gravity field, plus a good bit more. In fact, it could almost be called a gravimetric pansophia. Assuming only the knowledge of partial differentiation and about a one-semester background in general physics and general geology, it brings the reader to the frontier of the subject.

Not that a student with only such background should be advised to attempt it: the book, especially in its mathematical sections, is not easy reading. But the information is there, be it the transformations of a polar coordinate system, Molodenskii's operators, or Fredholm's integral equation.

The subject matter is divided to suit the author's interests. Pick, an applied mathematician, treats potential theory, geometry of equipotential surfaces (including the shape of the earth), theory of reductions of gravity data, and astrogravimetric leveling. Pícha's interest is the instrumentation, its history, its capabilities, and its application in the field. Vyskočil contributes the chapters that tell us what can, and what cannot, be learned from gravity data about the internal constitution of the earth.