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Introduction to the special issue

This special issue honors the research and mentorship excellence of Dr. Richard Shiffrin, the 2002 David E. Rumelhart Prize recipient. This prize was instituted in 2001, funded by the Robert J. Glushko and Pamela Samuelson Foundation. The first prize recipient was Geoffrey Hinton. The prize is awarded annually to an individual or collaborative team making a significant contemporary contribution to the formal analysis of human cognition. Mathematical modeling of human cognitive processes, formal analysis of language and other products of human cognitive activity, and computational analyses of human cognition using symbolic or nonsymbolic frameworks all fall within the scope of the award. In 2002, the prize selection committee consisted of Alan Collins, Mark Liberman, Anthony Marley, and James McClelland (chair).

This issue of *Cognitive Science* is the first of what will hopefully become a tradition of special issues related to Rumelhart Prize winners. We have already begun planning a special issue on computational linguistics in honor of the third Rumelhart Prize winner, Dr. Aravind Joshi, at the University of Pennsylvania. In some cases, the special issues will be based upon a single topic central to the research of the prize winner. In other cases, the issues will be comprised of research articles by colleagues, collaborators, or past students of the prize winner. This special issue pays tribute to the diversity and quality of research that Richard Shiffrin's students have gone on to conduct after leaving Dr. Shiffrin's laboratory, and so it is fitting that this issue for Dr. Shiffrin includes research by his previous students and collaborators. Dr. Shiffrin has been the mentor to a surprisingly large number of individuals who have developed noteworthy and fertile research programs. The research topics spanned by the seven articles of this issue include cognitive neuroscience, causal reasoning, human–computer interaction, memory, semantic representation, visual perception, priming, attention, and automaticity.

Despite the eclectic set of covered topics, shared themes and methods underlie the articles. The researchers strive to develop well-constrained formal models of cognition. The sources of these constraints include evolutionary (Geisler), optimality (Geisler, Huber, Shiffrin, Steyvers, Raaijmakers), neurophysiological (Huber, Schneider), pragmatic (Dumais), and computational (Dumais, Steyvers) considerations. Rather than restricting or holding back the development of theory, these constraints enable theorizing by directing cognitive scientists to positive formalisms and methods. A second theme in common to several of the manuscripts is the fertility of applying rational and Bayesian principles to human cognition. The apparent wisdom of this approach appears on the surface to be cast in doubt by the large number of empirical

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demonstrations of suboptimal and irrational human decision making, including the research for which Daniel Kahneman was awarded a 2002 Nobel Prize in economics. However, Bayesian, rational analyses always begin with limitations and constraints (as mentioned above), significantly reducing the apparent discrepancy between the approaches. Furthermore, failures of rational decision making notwithstanding, enormous progress in many fields has been made with Bayesian modeling. This point is emphasized by the articles in this issue—they demonstrate surprising depth to rational analyses of perception, memory, causal reasoning, and information access. Humans may not be built in the best way possible, but comparing our performance to formally devised gold standards of rationality has revealed both informative deviations from optimality and surprising cases where cognition apparently conforms to normative accounts.

1. A brief biography of Richard Shiffrin

Dr. Shiffrin received his Ph.D. from the Mathematical Psychology Program in the Department of Psychology at Stanford University in 1968, the year after David Rumelhart received his degree from the same program. Since 1968, he has been on the faculty of the Department of Psychology at Indiana University, where he is now the Luther Dana Waterman Professor of Psychology and distinguished professor. He developed the cognitive science program at Indiana University in the late 1980s, and was its director from its inception in 1989–2002. Shiffrin has accumulated many honors, including memberships in the National Academy of Sciences and the American Academy of Arts and Sciences, the Howard Crosby Warren Award of the Society of Experimental Psychologists, and a MERIT Award from the National Institute of Mental Health. Shiffrin has served the field as editor of the *Journal of Experimental Psychology: Learning, Memory, and Cognition*, and as a member of the governing boards of several scientific societies.

Shiffrin has made many contributions to the modeling of human cognition in areas ranging from perception to attention to learning, but is best known for his long-standing efforts to develop explicit models of human memory. His most recent models use Bayesian, adaptive approaches, building on previous work, but extending it in a critical new manner, and carrying his theory beyond explicit memory to implicit learning and memory processes. The theory has been evolving for about 35 years, and as a result represents a progression similar to the best theories seen in any branch of science.

Shiffrin's major effort began in 1968, with research (Atkinson & Shiffrin, 1968) that laid out a model of the components of short- and long-term memory and described the processes that control the operations of memory. The Atkinson–Shiffrin model encapsulated empirical and theoretical results from a very large number of publications and modeled quantitatively the relation of short- to long-term memory. It achieved its greatest success by showing the critical importance—and the possibility—of modeling the control processes of cognition. This 1968 chapter remains one of the most cited works in the entire field of psychology.

Shiffrin's formal theory was taken forward in a quantum leap with the Search of Associative Memory (SAM) model (Raaijmakers & Shiffrin, 1980, 1981). This was a joint effort with Jeroen Raaijmakers, then a graduate student. The SAM model quantified the nature of retrieval from

long-term memory, and characterized recall as a memory search with cycles of sampling and recovery. The SAM theory precisely incorporates the notions of interactive cue combination that are now seen to lie at the heart of memory retrieval. Another major step occurred when the theory was extended to recognition memory (Gillund & Shiffrin, 1984). Shiffrin and his former student initiated what has become the standard approach to recognition memory, in which a decision is based on summed activation of related memory traces. It was a major accomplishment that the same retrieval activations that had been used in the recall model could be carried forward and used to predict a wide range of recognition phenomena. The next major step occurred in 1990, when Shiffrin published two articles on the list-length effect with his student Steve Clark and his colleague, Roger Ratcliff (Ratcliff, Clark, & Shiffrin, 1990; Shiffrin, Ratcliff, & Clark, 1990). This research was of critical importance in that it established clearly that experience leads to the differentiation, rather than the mere strengthening, of the representations of items in memory.

In 1997, the theory evolved in a radical new direction in an important paper with another former student, Mark Steyvers (Shiffrin & Steyvers, 1997). Although the changes were fundamental, the new model retained the best concepts of its predecessors, so that the previous successful predictions were also a part of the new theory. The Retrieving Effectively from Memory (REM) model added featural representations, to capture similarity relations among items in memory. Building on earlier ideas by John Anderson, and related to ideas developed in parallel by James McClelland and Mark Chappell, Shiffrin used Bayesian principles of adaptive and optimal decision making under constraints to guide the selection of the quantitative form of the activation functions. In addition, storage principles were set forth that provided mechanisms by which episodic experience could coalesce over development and experience into permanent noncontextualized knowledge. This latter development allowed the modeling of implicit memory phenomena, in work that is just now starting to appear in journals, including a theory of long-term (Schooler, Shiffrin, & Raaijmakers, 2001) and short-term (Huber, Shiffrin, Lyle, & Ruys, 2001) priming. The short-term priming research showed that the direction of priming can be reversed by extra study given to particular primes, leading to another conceptual breakthrough. A Bayesian-inspired new model consistent with the REM framework explains this and many other findings by assuming that some prime features are confused with test item features, and that the system attempts to deal with this situation optimally by appropriate discounting of evidence from certain features.

2. An enduring tradition

A selected set of references to Richard Shiffrin's research is included here, sampled from a much larger set of over 100 scholarly works. This corpus of research attests to his impact in the specific areas of memory and attention, and more generally to formal modeling in cognitive science. The present set of articles demonstrates that this tradition of effectively combining empirical research on human cognition with formal modeling is alive and well. It is a testament to Shiffrin's effectiveness as a mentor that his students have been able to apply the modeling tools that they learned to areas far removed from Shiffrin's own research. As one of his current graduate students observed, "Rich creates an atmosphere that makes it easy

for people to succeed." The current articles corroborate this claim. The success that Shiffrin has had in his scientific career shines all the brighter for having worn off on his students and colleagues.

Selected research publications by Richard Shiffrin

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