EXECUTIVE SUMMARY

High-performance computer applications in the behavioral sciences

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This symposium revisited the 1985 conference on Advanced Computing for Psychology. That meeting examined the application of new supercomputers in the behavioral sciences. The present symposium reviewed high-performance computing as applied to psychological models, human vision, neural-physiological processes, and statistical analysis. The recent past and the projected future of high-performance computing in the behavioral sciences were evaluated.

Advanced Computing for Psychology, a previous symposium held in May 1985 (see Green & Null, 1985), was sponsored by the Federation of Behavioral, Psychological and Cognitive Sciences and the National Science Foundation. We may now look back on the past decade to witness the changes in supercomputing itself and in its application to the behavioral sciences. During the past decade, the meaning of supercomputers changed and the design of high-performance computers turned from the original Cray concept to other architectures. Sophisticated Cray computers produced stunning increases in the number of operations performed per second, yet speed alone proved to be only one aspect of high-performance computing that benefited behavioral scientists.

The present symposium was held to showcase supercomputer applications by leading behavioral scientists and to introduce future users to these research applications and procedures. These researchers show that scientific psychology can benefit from rapidly growing computer technologies that allow us to solve large and complex problems and to formulate our research issues more accurately by using new computer architectures.

The symposium also provided a forum for behavioral scientists in high-performance computer applications to share their experiences with other users and potential users. Such interactions, we believe, encourage networking among the behavioral scientists whose research questions

demand high-performance computing, and provide an educational forum for future users. Furthermore, this symposium identified the behavioral sciences as a scientific field to be reckoned with by the high-performance computing community and industry.

We have seen a change in the mainstay of supercomputing from Type IV, large-memory-based Cray computers, to massively parallel computers, to interactive desktops and powerful, economical workstations. Are *supercomputers* the best and most powerful? Today, high-end advanced computing also includes graphic workstations.

High-performance computing used to be within the purview of the physical sciences. Today, it is becoming increasingly useful to behavioral scientists investigating complex mathematical models of brain function, neural network models of cognition, and studies of human vision. Statistical and data analysis of large databases is now computationally feasible, owing to the vast increase in processing speed and throughput. Research in electromagnetic fields of the brain also benefits from high-performance computing.

In the physical sciences, high-performance computing is a unifying force. High-performance computer uses in fluid dynamics cut across various disciplines, from astrophysics to chemical engineering. Often developments and advances in one area are readily shared with other disciplines, which in return accelerates the developments in various substantive areas. Because behavioral scientists have not capitalized on such interdisciplinary interactions, this symposium on high-performance computing created opportunities for interactions among speakers and attendees.

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Five major topics areas were considered for this symposium: psychological models, the perception of space (Human Vision I), virtual reality and eyeball tracking (Human Vision II), neural and physiological processes, and statistical analysis. Future high-performance computing needs and challenges are summarized for each topic area below.

Psychological Models

Research in cognitive science relies heavily on advanced computers to simulate complex models of mental processes such as memory and text comprehension. Using massively parallel supercomputers, we can solve for a large number of parameters involved in cognitive science. But this has not shortened the time that it takes for a researcher to generate and evaluate models. There is a great need to merge the interactive capability of a desktop with the high-speed/large-memory capability of a supercomputer. This may help reduce the time required for a theorist to generate psychologically meaningful models, simulate models, and evaluate the fit of models to data.

The traditional supercomputer usages based on a batch mode do not suit the research needs of cognitive scientists. An additional challenge for cognitive scientists is to build a reasonable general-purpose model that is not too specific or too restrictive for general application to a natural cognitive operation. At present, the mere speed or memory provided by a supercomputer does not help shorten the path toward this goal. There is also a need for general software for testing models in order to reduce programming redundancy across researchers and to provide a uniform criterion for rejecting undesirable models.

Human Vision I: Perception of Space

The study of vision perception in particular has enjoyed the use of supercomputers to their maximum capacity. Research in the perception of motion and surface structures such as shading, texture, and color has progressed hand in hand with the advent of the more refined stimulus-generation capabilities of current supercomputers.

A realistic model of human visual perception, for example, demands a mathematical model with a large number of elements operating in parallel. It was envisioned in *Advanced Computing for Psychology* (Green & Null, 1985) that a massively parallel computer would help advance the research in visual perception because of its architectural similarity to the visual system. As it turned out, a massively parallel supercomputer was not easier for the researchers to program, nor did it help make more refined stimulus generation possible.

Instead, we saw a proliferation of powerful graphic workstations and even Macintosh or Pentium-based personal computers provide economical, speedy programming and good precision for stimulus generation. Such a progress is in part due to ready-to-use software tools made available for the SGI, SUN, and Macintosh. This is one of the areas where we see clearly that it is not the hardware itself that promotes research progress, but the software that reduces the programming time and effort.

Human Vision II: Virtual Reality and Eyeball Tracking

The animation and real-time processing on a supercomputer or a high-performance workstation allows more naturalistic images to be presented at a fraction of previous speeds, or the recording in real time of massive amounts of data. Monumental progress has been made in the area of virtual reality with the use of powerful graphic workstations and Macintoshes. Again, the progress was supported primarily by the advent of more sophisticated workstations and Macintoshes as well as the general graphic software tools made available by various vendors.

In the recording of eyeball tracking, which involves a massive amount of data equivalent to that of recording turbulence in physics, a large storage capacity is a must. Again, massively parallel computers are not the solution. Instead, a data compression scheme and cheaper and more reliable storage have aided researchers. We expect to see more powerful and economically feasible workstations in the near future, as well as a massive data storage device that will benefit this area even more.

Neural and Physiological Processes

Neural networks and electromagnetic imaging of brain functions demand massive data storage and fast arithmetic operations. Though neural networks were expected to benefit greatly from a massively parallel supercomputer because of its architectural similarity to the network connections, we have found much easier, and equally fast if not faster, manipulation of data by workstations. Physiological monitoring in real time requires a large data storage capacity. Real-time imaging demands speed combined with a large memory capacity. As in the life sciences, neural network problems and medical/physiological imaging are well suited for high-performance computing.

The future challenges foreseen by Suppes (1997) are not necessarily to be found in increased speed or in CPUs but in the difficulty of mapping physiological measures (EEGs) or neurons to a specific but simple day-to-day cognitive operation, such as mental addition or multiplication. The advances that we observed in physiological recording or imaging alone cannot be considered a breakthrough for the behavioral sciences if we cannot further the understanding of how brain functions are related to cognitive functions.

Statistical Analysis

Data and statistical analysis which involves large databases, many elements, or a statistical operation with nonlinear iterative processes can benefit from high-performance computing. In addition to the areas cited in *Advanced Computing for Psychology* (Green & Null, 1985) such as Monte Carlo simulations, modern item response theories, and covariance structure models, we saw an example of microcomputers in a cluster working as a parallel computer. A combination of a personal computer cluster, a workstation cluster, and a high-performance computer allowed complex statistical analysis to be completed in seconds, instead of months, for users connected

by the Internet. This helps shorten the time that the user takes to generate and examine statistical questions.

The iterative operation of smoothing a function, as opposed to estimating a parameter, requires an iterative computation of global minima or maxima. A massive parallel computer proved not to be helpful in such statistical computation, though some time-series data processing could exploit its data level parallelism. A moderate level of parallelization—that is, a moderate number of nodes—seems to be beneficial for this area. As was the case in the psychological modeling, the future need seems to be in providing interactive capability.

Post Notes

This symposium was sponsored by the University of Minnesota Supercomputer Institute, the College of Education and Human Development, and the Federation of Behavioral, Psychological and Cognitive Sciences. The organizing committee consisted of Lynne Edwards, Department of Educational Psychology and Supercomputer Institute; Stephen Link, Federation of Behavioral, Psychological and Cognitive Sciences; and Cynthia Null, NASA Ames Research Center.

In addition to talks, presentations, and discussions, the symposium included tours of high-performance computing facilities at the University of Minnesota. These in-

cluded the IBM Workstation Cluster, the Laboratory for Computational Science and Engineering, and the supercomputing facilities at the Minnesota Supercomputer Center, Inc.

The symposium was opened with an overview of high-performance computer architectures presented by representatives from Cray Research, Inc., Silicon Graphics, Inc., and IBM. The sessions were chaired by Stephen Link, Albert Yonas, Cynthia Null, Jay Samuels, Mark Davison, and Lynne Edwards.

In closing, the organizing committee thank the invited speakers for the stimulating presentations, the attendees for their active discussions, the sponsors for their outstanding support and encouragement for scientific psychology, and Editor Robert Proctor and the Psychonomic Society for the publication of these proceedings. Last, we note with regret the passing this year of Seymour Cray, the founder of supercomputing, whose powerful ideas advanced the role of computing in our science.

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APPENDIX
Participants in the Conference on
High-Performance Computer Applications in the Behavioral Sciences

Name	E-mail Address	Research Interests
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