Position Statement of

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for

Science of Design: Software-Intensive Systems

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Position

Software-intensive systems are constructed, ultimately, to serve human needs. Indeed, many software-intensive systems today interact extensively with humans to fulfill those needs. Finally, systems are constructed by humans, often by teams of people with diverse backgrounds. Since people are intimately involved in the purpose, construction, and operation of software-intensive systems, the design of such systems must consider the needs, desires, capabilities, and limitations of humans to be produce the most effective outcome possible. Thus, a science of design must also include the behavioral sciences, not in general, but as applied to software-intensive system design.

As an engineer and psychologist, my position has long been that to affect the design of software systems, behavioral science must package its knowledge and methods in a way that allows engineers to use it. If the methods and knowledge from psychology or social psychology are not yet codified sufficiently to be used without extensive training in those disciplines, at very least the behavioral scientist must participate in an interdisciplinary design team using language that makes contact to software engineers and methods that are comprehensible to software engineers, in a manner that is timely to the software engineering process.

This position opens many questions in the science of design. Some fall within the traditional questions of Human-Computer Interaction, such as

- *Can we predict the behavior of software users from design ideas or specifications alone, in advance of building or even prototyping the system?*

This was traditionally a question of cognitive psychology (single user at a desktop), but has moved into the realm of social psychology (multi-user systems, systems of people and software agents), perceptual psychology (ambient displays, virtual reality), and most recently a mixture of science and esthetics (e.g., predicting the experience of fun, enjoyment, or other emotional reactions). Research supported by the NSF and other government agencies and industries have made progress on some of these areas in the past 20 years. For example, it is possible to quantitatively predict the execution time of routine tasks by skilled workers from specifications of a system alone, possible to predict the relative learning time of different designs, and possible to construct adaptable teaching systems that approach the effectiveness of one-on-one human tutors in constrained domains like algebra or geometry. All are significant accomplishments, based on rigorous behavioral science, that fill a specific need in some software-intensive systems, but many more questions are still to be explored and resolved.

The position that behavioral science must bring its knowledge and methods 95% of the way to the process of software design and construction opens many questions where the process of software design and software designers are the subject of study themselves. Among them are

- *How do software design teams work, so that appropriate methods can be developed to bring behavioral science to the process?*
- *What methods are effective in bringing human concerns to the design process at appropriate times?*
- *To what characteristics of effective methods can success be attributed, so that additional effective methods can be developed?*
- *What are the best processes for infusing human concerns in the design of software systems? Interdisciplinary teams? Training software developers in behavioral methods or behavioral scientists to develop software? Particular development processes? Tools? And how should we assess the effectiveness of proposals such as these?*

These and many more questions could be profitably included in a science of design.

Background of Applicant

Dr. Bonnie John is an engineer and cognitive psychologist (B.Eng. 1997, The Cooper Union; MS in Mechanical Engineering from the Design Department at Stanford University, 1978; Professional Engineers License in the State of New York, 1980; Ph.D. in Cognitive Psychology, Carnegie Mellon University, 1988). She is current an associate professor in the Human-Computer Interaction Institute in the School of Computer Science at Carnegie Mellon University, but she was a systems engineer at Bell Laboratories (1977-1983) before returning to school and academe. She is the Director of the Masters of Human-Computer Interaction at CMU, a professional masters degree that produces leaders in industrial interdisciplinary teams. Her research has included predictive computational modeling of human behavior, where her most economically prominent accomplishment was to save NYNEX two million dollars a year by predicting, and explaining, why a technologically and ergonomically superior operators workstation would actually cost the company money in the field rather than save it, as was expected by both the manufacturer and NYNEX management. (This prediction was later confirmed by extensive field trials of the equipment.) She has extended these modeling techniques into more highly interactive systems and learning and has created tools that make the construction of such models more accessible to non-psychologists. She has investigated the effectiveness of several prominent usability evaluation methods, including Cognitive Walkthrough and think-aloud usability tests. In the past few years, she has joined with Len Bass at the Software Engineering Institute to produce materials and methods for evaluating software architecture designs for their potential to support usability concerns. They are currently participating in the NASA-supported High Dependability Computing Program, where usability is considered an aspect of dependability, applying their techniques to NASA testbed projects, most notably, the MERBoard collaborative workspace for engineers and scientists who will analyze the data sent from the rovers scheduled to land on Mars in January 2004.
Details of Dr. John's background and research can be found at www.cs.cmu.edu/~bej/