Neo-Symbiosis

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INTRODUCTION

The purpose of this article is to re-address the vision of human-computer symbiosis expressed by J. C. R. Licklider nearly a half century ago, when he wrote: "The hope is that in not too many years, human brains and computing machines will be coupled together very tightly, and that the resulting partnership will think as no human brain has ever thought and process data in a way not approached by the information-handling machines we know today" (Licklider, 1960). Unfortunately, little progress was made toward this vision over 4 decades following Licklider's challenge, despite significant advancements in the fields of human factors and computer science. Licklider's vision was largely forgotten. However, recent advances in information science and technology, psychology, and neuroscience have rekindled the potential of making the Licklider's vision a reality. This article provides a historical context for and updates the vision, and it argues that such a vision is needed as a unifying framework for advancing IS&T.

BACKGROUND

Licklider's statement is breathtaking for its vision, especially considering the state of computer technology at that time, that is, large mainframes, punch cards, and batch processing. It is curious to note that Licklider did not use the term symbiosis again, but he did introduce more visionary ideas in a symbiotic vein. An article he co-authored with Robert Taylor titled *The Computer As a Communication Device* made the bold assertion, "In a few years, men will be able to communicate more effectively through a machine than face to face" (Licklider & Taylor, 1968). Clearly, the time estimate was optimistic, but the vision was noteworthy. Licklider and Taylor described the role of the computer in effective communication by introducing the concept of "On-Line Interactive Vicarious Expediter and Responder" (OLIVER), an acronym that by no coincidence was chosen to honor artificial intelligence researcher and the father of machine perception, Oliver Selfridge. OLIVER would be able to take notes when so directed, would know what you do, what you read, what you buy and where to buy it. It would know your friends and acquaintances and would know who and what is important to you. This article made heavy use of the concept of "mental models," which was relatively new to the psychology of that day. The computer was conceived of as an active participant rather than as a passive communication device. Remember that when this article was written, computers were large devices used by specialists. The age of personal computing was off in the future.

Born during World War II, the field of human factors engineering gained prominence for its research on the placement of controls, widely known as knobology, which was an unjust characterization. Many important contributions were made to the design of aircraft, including controls and displays. With strong roots in research on human performance and human errors, the field gained prominence through the work of many leaders in the field who came out of the military: Alphonse Chapanis, a psychologist and a Lieutenant in the U.S. Air Force; Alexander Williams, a psychologist and naval aviator; Air Force Colonel Paul Fitts; and J.C.R. Licklider. Beginning with Chapanis, who realized that "pilot errors" were most often cockpit design errors that could be corrected by the application of human factors to display and controls, these early educators were instrumental in launching the discipline of aviation psychology and human factors engineering that led to worldwide standards in the aviation industry. These men were influential in demonstrating that the military and aviation industry could benefit from research and expertise of the human factors academic community; their works (Fitts, 1951) were inspirational in guiding research and design in engineering psychology for decades. Among the most influential early articles in the field that came out of this academic discipline was George Miller's (1956) "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity to Process Information," which helped to usher in the field of cognitive science and application of more quantitative approaches to the study of cognitive activity and performance.

An early focus of human factors engineering was to design systems informed by known human information processing limitations and capabilities, systems that exploit our cognitive strengths and accommodate our weaknesses (inspired by the early ideas represented in the Fitts' List that compared human and machine capabilities (1951). While the early HFE practice emphasized improvements in the design of equipment to make up for human limitations (reflecting a tradition of *machine centered computing*), a new way of thinking about human factors was characterized by the design of the human-machine system, or more generally, *human-* or *user-centered computing* (Norman & Draper, 1986). The new subdiscipline of interaction design emerged in the 1970s and 1980s that emphasizes the need to organize information in ways to help reduce clutter and "information overload" and to help cope with design challenges for next-generation systems that will be increasingly complex while being staffed with fewer people.

There have also been theoretical developments in cognitive psychology that provide a foundation for Licklider's vision. Central here is the work by Kahneman (2002, 2003). In his effort to reconcile seemingly contradictory results in studies of judgment under uncertainty, he has advanced the notion of two cognitive systems introduced by Sloman (1996) and others (Stanovich & West, 2002). System 1, termed Intuition, is fast, parallel, automatic, effortless, associative, slow-learning, and emotional. System 2, termed Reasoning, is slow, serial, controlled, effortful, rule-governed, flexible, and neutral. Cognitive illusions, which were part of the work for which he won the Nobel Prize, as well as perceptual illusions, are the results of System 1 processing. Expertise is primarily a resident of System 1 as is most of our skilled performance such as recognition, speaking, and driving. System 2, on the other hand, consists of conscious operations and is commonly thought of as thinking.

System 1 is effective presumably due to evolutionary forces, massive experience, and by constraining context. Most of the time it works quite effectively. System 1 uses nonconscious heuristics to achieve these efficiencies, so occasionally it errs and misfires. Such misfires are responsible for perceptual and cognitive errors. One of the roles of System 2 is to monitor the outputs of System 1 processes.

NEO-SYMBIOSIS: A VISION AND FRAMEWORK FOR CONDUCTING RESEARCH

Licklider's notion of symbiosis does require updating. The term "man/computer symbiosis" is both politically incorrect and factually inaccurate. "Human/machine symbiosis" is preferable. There is also a problem with the term symbiosis itself. Symbiosis implies a co-equality between mutually supportive organisms. However, humans must be in the superordinate position. Dreyfus (1972, 1979, 1992) has made compelling arguments that there are fundamental limitations to what computers can accomplish, limitations that will never be overcome. In this case it is important that the human remain in the superordinate position so that these computer limitations can be circumvented. At the other extreme, Kurzweil (1999) has argued for the unlimited potential of computers. Should it be proven that computers, too, have this unlimited potential, then some attention needs to be paid to Bill Joy and his nightmarish vision of the future should technology go awry (Joy, 2000). In this case, we humans would need to be in the superordinate position for our own survival. Griffith (2005) has introduced the term neo-symbiosis for this updated version of symbiosis.

Kahneman's two system theory plays a central role in neo-symbiosis. It is the System 2 processes that require computer support, not only with respect to the pure drudgery and slowness of System 2 processes, but also with respect to the monitoring of System 1 processes. In most cases, it is a mistake to assign System 1 processes to the computer. This was the fundamental error in many automatic target recognition and image interpretation algorithms that attempted to automate the human out of the loop. The perceptual recognition processes of most humans are quite good. System design should capitalize upon these superb processes and provide support to other areas of human information processing such as search (to overcome a tendency to overlook targets), interpretation keys to provide support for the recognition processes. Other types of System 2 support could include the augmentation (not replacement) of human reasoning processes, support to facilitate adjusting to changes in context to maintain situational awareness and computational support.

A related approach is Joint Cognitive Systems (JCS's) (Hollnagel & Woods, 2005; Woods & Hollnagel, 2006), which represents a specific implementation of cognitive systems engineering. As the term JCS implies, this approach views the human-computer system as a combination of human and machine cognition. Another way of looking at this is that the human is a component of the computer architecture (consistent with our view of neo-symbiosis). In their two volumes, Hollnagel and Woods have developed a sophisticated approach to system design, but it does not draw much from either cognitive psychology or cognitive neuroscience. Neo-symbiosis draws liberally from both cognitive psychology and cognitive neuroscience. In our view, neo-symbiosis is a subset of cognitive systems engineering that may be applied to enrich the field through its focus on human cognition and the supervisory role of humans in joint cognitive systems.

Another related approach is hedonomics. Hedonomics (Hancock, Pepe, & Murphy, 2005) can most easily be thought of as designing technology to climb Maslow's (1970) Hierarchy of Needs. According to Maslow, human needs can be arranged in a hierarchy or pyramid beginning with physiological needs at the base, then proceeding up to safety, love and belonging, self-esteem, and ending with self-actualization at the top. An interesting exercise is to consider how technology can, and sometimes does, facilitate meeting these needs. Hedonomics is certainly in the spirit of neo-symbiosis. Both hedonomics and neo-symbiosis have the same destination. But in its present state, hedonomics presents what is effectively a *brochure* of the destination,