The Strong Cognitive Stance as a Conceptual Basis for the Role of Information in Informatics and Information System Design

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Abstract

This paper analyzes different approaches that have been taken to describe and utilize cognitive space for use with information systems. A "strong cognitive stance" on the role of information for information systems is presented as derived from the analysis, with implications for information system designers, evaluators and users. The goal is to provide designers and evaluators of information retrieval systems with concrete insights into how to apply cognitive perspectives. Different perspectives, which lead to the strong cognitive stance, are examined in sections addressing the cognitive basis of information, user-based empirical study, laws of human cognition, components of consciousness, and the cognitive emphasis in current IR research. A following section identifies aspects of cognitive space, and presents the derivation of the strong cognitive stance as an interpretation for the role of cognitive space in information system development.

1. Introduction: The Human Aspects of Cognitive Space

Many groups of researchers and developers are interested in trying to facilitate successful interaction between humans and computer systems. "Success" may be measured in a variety of ways, and the array of system types and purposes is equally varied. People employ computer systems for word processing, financial management, data communication and many other tasks for the office environment. Computer systems are used for routing telephone calls, planning menus, and designing products. People may use computer systems as surrogates for their own memories by storing important facts and figures for later retrieval. Many types of computer systems are applied to responding to various information needs: help systems, database systems, bibliographical retrieval systems, and so forth.

This work will present approaches to the human experience which may be useful for designers of computer systems, especially information retrieval systems.

At the core of the work is the notion of cognitive space. At the outset, we can define cognitive space as *the domain of concepts and relations in which the human experience takes place*. This definition is intentionally broad, as it is the purpose of this work to examine broad approaches to cognitive space in order that an increased understanding can lead to better applications.

Cognitive space is not just what is known (e.g., facts about the world), but also the dynamics by which knowledge is acted on, used, changed, etc. Processes in cognitive space are those required to store and retrieve knowledge, and also processes for integrating perceptions with experience, desires, the physical self, and so on.

As we start our survey of cognitive space, we will draw only the loosest of boundaries around our notion of what cognitive space is. In this section, some of the breadth of cognitive space will be explored; the next section examines some ways in which the outcomes of our investigation might be put to practical use.

The human experience is made up of many overlapping phenomena, all of which have some bearing on cognitive space:

- knowledge
- thought, self-reflection
- memories and memory retrieval
- mental models of the self, others, and situations
- biological components (brain structures; links to the body)
- perceptual systems; haptic systems
- chemical processes (neurotransmitters; hormones)
- social and historical factors

Various approaches to investigation and explanation of the human experience are described below. Throughout our investigation, the focus will be to first investigate different perspectives as they might contribute to our understanding of cognitive space. Second, it will anticipate how these perspectives might contribute in practical ways to human-computer interaction and information system design.

2. Why Study Cognitive Space?

The need for an understanding of cognitive space in order to fashion effective systems for human-computer interaction is clear. User-based methodologies for creating computer interfaces are the norm for commercial software enterprise (e.g., Ericsson, 1993) and ongoing study is made of better ways for designing computer interfaces about the needs of their human users (e.g., Dervin & Nilan, 1986; Shneiderman, 1992; Norman et al., 1986). Many existing systems have demonstrated the utility of applying detailed knowledge about user processes, knowledge, and needs (Apple's MacOS desktop interface remains an excellent example).

The variety of definitions and approaches to cognitive space is indicative of its importance to those who seek to facilitate human-computer communication. Humans send messages to computer systems in the form of commands, menu selections, button clicks etc. It is the job of the computer system designer to insure the human user will be able to achieve a desired result. In the simplest of systems—for example, an automated call-routing system at a firm, operated by a touch-tone telephone—the system designers' understanding of the user population's cognitive spaces does not need to be extensive. A general knowledge of language, information need, and available outcomes is sufficient to create a usable system (not to say that all are easily navigable!).

In more complex systems for human-computer interaction, much more detailed knowledge of cognitive space is required. The MacOS desktop system model (see Laurel, 1990) is an outcome of detailed investigation into cognitive space of the user population, based on earlier work at Xerox PARC on how people manipulate graphical objects. The developers combined their notion of how graphical representations of objects (icons) could be arranged on a virtual desktop with an understanding of how a child approaches the world. The outcome was a revolution in how popular computing interfaces were created.

Less widely-circulated examples of application of study of cognitive space to produce an effective human-computer interface exist. Development of the knowledge base for expert systems, for example, involves codifying the cognitive spaces of a group of human domain experts in a machine-readable form. Research on flight cockpit design has a long history of effort at understanding cognitive space of pilots in order to present critical information effectively (e.g., Aviation Week & Space Technology 1985).

3. Matching Cognitive Space with Information Space

When humans interact, they benefit from great experience and a substantial skill set for communicating with other humans. The result is that people communicate using far more than words, and even more than non-verbal communication, vocal quality, and the like adds. Skills include the ability to apply relevant past experiences to a situation, to disambiguate ambiguous statements, to maintain a mental model of the other person and to utilize latent content or context to gain further understanding of what it said.

When humans interact with computers, however, computer systems have very limited ability to utilize more than simple utterances or keystrokes to choose an appropriate response. Were computer systems to have a model of human cognitive space (or spaces), further data could be brought to bear in order to create an optimal response.

The information spaces utilized by computer systems are more easily understood than human cognitive space. Information is codified in a system's information space, and relations among various items of information is known or knowable. The full variety of content, allowable input, processes and possible output is readily accessed in almost all computer systems (even neural networks and other types of systems in which the content or process is not as easily known are accessible to study of their various responses to various input).

Information space for systems is distinguished from cognitive space of humans by being more knowable: we can easily isolate a computer system from the surrounding environment and create a controlled experiment, something notoriously difficult (and sometimes unethical) with humans. Changes to information space happen on known schedules, usually due to input from the environment. Few computer systems have the capacity to re-organize their information space based on past interaction, yet humans do this constantly.

The processes of a computer system are well-known. These may be analogous to the many biological, chemical, social and other processes in the human domain. Yet computer systems (again, with very few exceptions) do not engage in processes which are not well-understood, traceable, and entirely due to causal relations among various system components.

The information space of a computer system may be defined as *the sum of the data, processes, and means of communicating that a system uses*. What can we say of a computer system for which the information space exhibits qualities of human cognitive space, as discussed here? We would need to consider the computer system as having important components of human-like intelligence.

What can we say of an information space which includes, among other things, models of the cognitive space of a user, or information need situations, or human processes of information seeking and use? We would predict that the computer system that had access to such an information space would have potential for greatly facilitated performance in its servitude to humans. This performance would be expected because the computer system would have a sound foundation to implement many of the skills which humans utilize for communication, as listed at the start of this section.

The rest of this paper examines the perspectives of authors whose work has impact on our understanding of cognitive space and derives from them a strong cognitive stance on information systems. In addition, a list of qualities for cognitive space that emerges from the theory and research is presented.

3.1 The Creation of Experience: Autopoiesis

The relation between a world "out there" and what is perceived is not direct. Psychologists and others have investigated a vast array of physical, social, psychological, experiential, and other states that effect how what is perceived may be different than some "objective" state in the world. A perspective brought forth by Maturana and Varela (1987) starts not with a state in the world, but with a cognitive state. They present "cognition not as a representation of the world 'out there,' but rather as an ongoing bringing forth of a world through the process of living itself" (p. 9).

This self-creating role of cognition is derived from an extensive analysis of the basis of life itself. Although everyday experience is somewhat removed from the necessity to distinguish "life" from "non-life," an investigation of the nature of life yields a surprising uncertainty over what constitutes life. For the future, we may be addressing whether artificially intelligent machines are alive, or whether collectives of nanomachines constitute life. Historically, biologists and others have attempted to discover the early origin of life, and to understand why life started on Earth in the first place.

Maturana and Varella present *autopoiesis* as the basis for separating life from non-life. An *autopoietic organization* is an organization which is continually self-producing. From the molecular level, the cellular level, and the organism level, it seems evident that self-production is constant. Humans, for example, maintain a relatively constant body temperature, height, etc. through continual interaction with the environment (e.g., eating and moving) and an incredible number of highly integrated internal processes. Single-celled organisms maintain cell walls, replicate through various processes, and similarly interact with their environment.

The biological role of autopoiesis is not as illuminating for the current discourse as the cognitive role. In considering how biological objects perceive the world, Maturana and Varella present cognition as an autopoietic process. The process of perceiving the world is a constant process of creating a perception of the world.

The notion that there is no reality apart from our perception of that reality is familiar to several philosophies and social scientific viewpoints. Maturana and Varella go an additional step, and an important one, in presenting the creation (and maintenance) of the personal realities which people exist in as an ongoing and self-producing process.

If this view is accepted, a direct implication for information seeking and use may be drawn. In the weaker and more common notion of reality as a personal construction, is would be incumbent on system designers to understand that a particular piece of information—say, a document or bibliographic citation—cannot be thought of as separable from a human's perception of that piece of information.

Maturana and Varella's view necessitates a stronger implication: any information presented to an individual will play a role in shaping the reality in which that person lives. As part as an autopoietic process, phenomena which are encountered through information system utilization fit with other stimuli from the environment in contributing to the continual self-creation of an individual (human).

Phenomena which are perceived will generally impact on cognitive processes; physical phenomena (such as light or food) will generally impact on physical processes. Thus the continuum of various types of objects in the environment is approximately matched by a continuum of autopoietic processes in an organism.

3.2 Consciousness and Information: Cognition as a Fundamental Phenomenon

David Chalmers (1995) has made perhaps the strongest statement about the relation between information in the environment and cognitive state. He is concerned with the role of neurobiological processes in consciousness. In Chalmers' view, there are two types of problems surrounding the investigation of human consciousness. The "easy problems" (which Chalmers insists are not really easy at all) are concerned with the role of physical brain states in perception. For example, an easy problem, which Chalmers believes will be solved by neurobiologists, is how particular visual stimuli relate to human perceptual systems. Another easy problem has to do with understanding how people integrate the myriad stimuli in their environment into a single perceptual experience.

The "hard problems" have to do with subjective experience. An understanding of perception of phenomena, for example (an "easy problem") does not explain the experience of consciousness which people have, nor the feelings one has when stimuli to be experienced are encountered. For example, an easy problem might address how someone might perceive a painting in a museum, but description of what the art means for that person is a hard problem.

Chalmers suggests that consciousness may be a new type of *fundamental phenomenon*. As such, consciousness could not be measured as any subset or combination of something else, just as other fundamental phenomena such as electromagnetic waves or distance cannot be explained as combinations or reductions of other phenomena. As such, the study of consciousness should not start with the reductionist approach of examine particular neurological or biological functions which might combine to produce states or levels of consciousness, but instead must start with consciousness itself as a building block, and then expand to include notions of how consciousness, as a fundamental process, relates to other processes (such as neural firing patterns, neurochemical reactions, etc.).

After presenting consciousness as a fundamental phenomenon, Chalmers seeks to describe or derive psychophysical laws based on consciousness (rather than on other phenomena). He suggests that information may be directly related to consciousness—that information in the environment directly corresponds to conscious states. For example, the presence of a particular color pattern can be related directly to the conscious experience of that pattern. The color pattern contains information, and the conscious experience is essentially an internal representation of that information.[1]

Based on Chalmer's logic, the role of information in creating experience is paramount. Essentially, a reduction of all experience-producing phenomena to "information" is indicated. Is this consistent with other views on human perception, cognition, consciousness, etc.? It appears to be consistent, and also consistent with many approaches taken to describing experiences with information systems such as the value-added approach (Taylor, 1968), sense-making approach (Dervin, 1986), and situational-based approaches (Schamber et al. 1991).

From Chalmer's analysis, direct implications for information system designers may be derived. One implication is that the presence of information is dependent not on some absolute external phenomenon, but on a particular human's conscious state as it relates to that phenomenon.[2] Another implication is that information seeking and use behavior is not separable from other human behaviors and experiences. Perhaps the most important implication is that maximum effectiveness of information systems in producing information to address information needs (whether or not maximum effectiveness is truly achievable) could only be obtained with a detailed understanding of the conscious state of the information seeker.

The relationship between information in the environment and conscious state presented by Chalmers is direct, but without any particular means of measurement or assessment. As such, there is no implied path for information seekers or system designers to take in making use of the relationship. Concrete procedures that may be derived, apart from the implications described above, create restrictions: system designers or information seekers should not treat information as being separate from the conscious

[1] Chalmers makes use of Shannon & Weaver's Information Theory to present his views, which is unfortunate as the theory was not intended to apply to the cognitive domain. However, modern approaches to the measurement and perception of information, such as those presented elsewhere in this paper, could be substituted without harming Chalmers' arguments.

[2] This does not necessitate the human be consciously aware of the phenomenon, merely that, in Chalmer's terms, there is an internal representation of the information.

state of whoever is encountering that information; performance of an information system cannot be assessed separately from the conscious state of an information seeker.

3.3 Measurement and Cognitive Movement: Multidimensional Scaling

Numerous methods exist for the measurement of human cognitive phenomena. Those most commonly found in day-to-day life include opinion polls, surveys, and other pen-and-paper methods. These methods do not try to understand the processes by which, for example, opinions are formed and linked to action. Rather, they assess responses to particular questionnaire items etc. to see how responses to those items (which are linked to independent variables) may be used to understand, predict, or control items of interest (the dependent variables). As such, the majority of experimental, survey, interview, and ethnographic methods for scientific inquiry into human phenomena are useful for examining behaviors or measuring variables, but do not touch on the cognitive processes which (as most perspectives agree) lead to those behaviors.

Some scientists have produced methods for examining cognitive processes more closely. Multivariate statistical methods offer one approach to examining the latent or hidden qualities of survey data. One such approach is multi-dimensional scaling (MDS), in which a matrix of pair-by-pair measures of relations among items may be analyzed to produce a single solution in which all items are related metrically to all other items. Woelfel and his colleagues (see especially Woelfel and Fink, 1980) have developed the Galileo theory and method of human cognitive processes based on measurement with a variation of MDS (cf. Kruskal and Wish, 1984).

The Galileo survey consists of a set of paired-comparison items, for which respondents are asked to assess the dissimilarity of the pairs, based on an arbitrary cognitive ruler. For example, a survey dealing with pizza might offer paired comparisons for each of *cheese, fresh toppings, tasty sauce, hot, fast delivery*, and *good price*. An arbitrary ruler might be, *tasty sauce and fast delivery are 100 units apart*. Respondents would come up with a numeric difference score for every pair of terms (in this case, 6 terms would yield `[6 * 5] / 2 = 15` pairs). The matrix of paired comparisons is used as input to the MDS statistical procedure. The Galileo researchers have produced an array of statistical tools for extracting appropriate items from open-ended data, for examining time-series data, and for testing hypotheses on the relations among particular items.

The advantage of the Galileo method, and other MDS techniques, is that the outcome of the survey process (which, like other survey processes, is typically accomplished utilizing a sufficiently large sample to give statistical confidence in the results) is a complete metric space. That is, all items measured have some measured relationship to all other items in the space. Compared to a typical survey methodology (for example, one utilizing Likert scales), the relations among items are far richer. The generation of a metric space enables testing of the Galileo theory.

Galileo theory posits laws of cognitive processes similar to the laws of physics. In a Galileo cognitive space, survey items (referred to as “concepts”) have not only location, but also cognitive equivalents to mass and velocity. “Mass” is associated with how much knowledge and certainty exists about a concept. “Velocity” is simply the tendency of a concept to move (or sometimes oscillate) relative to other concepts over time. The Galileo cognitive space is not an empty space with occasional concepts in it, such as graphical depictions of the solar system. Rather, it is akin to an Einsteinian space-time, in which forces exist between items in the space, such that there is no truly empty space, only areas of more greatly concentrated “mass” and their associated forces.

The outcome of the Galileo method’s ability to measure relations among concepts combines with the theory (supported by empirical evidence) of processes analogous to those of physical space, yields powerful means of examining some of the processes of cognition. Galileo includes definitions and processes for attitudes, beliefs, changes in belief, learning new concepts and relations, and group- or mass-communication interaction. There are areas which Galileo does not address, however. The most relevant of these for the current discussion is that there is no notion of how people come to have consciousness—the processes which lead from a collection of concepts and relations to self-awareness.

3.4 Societies of Cognitive State: The Society of Mind

A perspective on cognition developed for computer simulation of human intelligence is Minsky’s (1986) *society of mind*. Minsky took a reductionist perspective, but without positing a single “whole” which is made up of the parts he reduced. He examined areas as varied as the human visual system, balance, temperature regulation, speech, and self-reflection. In his examinations, he was impressed with the variety of inputs, outputs, and processing which must take place for various subsystems, and the relatively limited extent to which most needed to interact.

Minsky offered the society of mind as a solution to the problem of human cognition, also as a goal for developers of artificial intelligence (AI) . By assembling subsystems, and linking the subsystems together in a hierarchy, AI could be achieved. The individual subsystems are not themselves simple! For example, vision is an area of ongoing study for robotics and allied fields which has produced limited success. Psychologists studying human perception have had similar limited success in understanding how vision occurs in humans (or other living creatures).

Cognitive scientists frequently analyze different components of the human experience separately, and create computational models of how these components interact. Johnson-Laird (1988) offers a complete description of this computational view of human cognition. Minsky does not necessarily posit that all components of the society of mind may be successfully modeled on a computer, but such modeling or simulation is his long-term goal.

Once various subsystems are created, they need to be linked together in a hierarchical network, although cross-hierarchical communication is also possible. At the top of the hierarchy are the subsystems responsible for self-reference, consciousness, etc. (Minsky's argument is reminiscent of Freud's notion of the id and ego as semi-hidden overseers of the human experience.) Like the other perspectives on human cognition mentioned here, Minsky's society of mind is useful for some things, but less useful for others. As a practical road map for AI researchers to follow, it makes sense: work on the many subsystems can proceed and succeed without disappointment that true human-like intelligence does not result.

The society of mind is an effective model for focusing on what we know about and identifying what areas we know less about. Minsky does not offer insight into how consciousness arises, yet he gives some ideas about how consciousness might be related to other aspects of human existence.

3.5 Getting from Here to There: Sense Making

The empirical work of Brenda Dervin and her colleagues has identified order in what might otherwise appear to be chaotic or unknowable human experience (Dervin, 1986). Through her "sense making" method of structured interviews and content analysis, categories of common human experience emerge for any human activity. The sense making approach is most frequently used to assess information needs. For example, the information needs of someone visiting a doctor, or using a word-processing system for the first time, or judging the weather. A structured interview extracts a timeline of experiences along with information needs and qualities of the information needs (for example, how an answer to a question is expected to help).

The timeline interview data are analyzed across respondents to extract commonalties in the experiences. Perhaps counter-intuitively, empirical evidence shows that even the most difficult or individual processes exhibit many common steps in the process and common information needs across individuals.

After generating a picture of common information need experiences associated with a process, an information system can be designed to best address the information needs for people in similar situations. Examples include brochures, online help systems and information kiosks. This notion of cognitive space is a practical one: the emphasis is on identifying information needs that people commonly have in a situation, so that the information needs may be anticipated or met *a priori*.

Different practical purposes yield different approaches to modeling the cognitive space. The same set of interview data may be analyzed for affect (good, bad, or indifferent), time focus (past, present, future), type of need (who, what, when, where, why, how), the nature of the reason for the information need (get further information, pass a barrier, choose an alternate path, make plans, etc.), or other qualities. As such, there is no attempt to gain a complete understanding of a cognitive space. Rather, the focus is on identifying common areas of experience for practical use in understanding and meeting information needs.

In addition to demonstrating the utility of structured interviews and content analysis for extracting common human experiences, Dervin's approach confirms that aspects of cognitive space are shared across individuals. The existence of activities which many people engage in, regardless of whatever else they might share, produces commonalties in cognitive space. For example, people who used a computerized desktop publishing systems to produce brochures or newsletters were found to have shared experiences during the learning process, and shared questions in the steps of producing their brochures and newsletters (Nilan et al., 1989).

Past experience, factors of attention and perception, and individual goals and desires prevent different people from having the exact same experience of any given occurrence. Yet the sense making methodology has identified clearly that there are many aspects of cognitive space that are shared across individuals due to common experiences. These are not contrary statements—rather, they inform us that cognitive space is built (at least partially) from experiences, and that some aspects of cognitive space are shared regardless of individual differences.

3.6 Problem Space and Cognitive Models in Information Retrieval

The interaction between a particular problem or information need situation and the larger cognitive domain in which such a problem exists has been approached by several different researchers. The MONSTRAT model (Belkin, 1984.) and the ASK hypothesis which came before it (Belkin et al., 1982) are fully-formed treatments of how human interaction with information systems might be more fruitful. ASK (Anomalous States of Knowledge) focuses on the anomaly, or area of uncertainty, which led the user to seek out information. This model moves the focus of information retrieval (IR) systems from matching queries to document surrogates (the traditional model) to presenting information which would meet an information need.

MONSTRAT incorporates many different components of IR models into an integrated view of IR development and evaluation. Components include models of the user, of transformation processes between user needs and system contents, and mapping user representations onto system representations. Ingwersen (1992) adds the role of domain models, system models (generated by system designers), and processes for facilitating feedback and generating responses. These models are of critical importance for cognitive approaches to IR, as it is a user's *model* of a system, its contents and her own problem state which dictates interaction, not some objectively measurable information need.

Models of the self, models of a situation, models of another person, and models of how the other sees the self are primary aspects of human existence. Those types of models were proposed by Mead (1960), along with the assertion that human beings, not lesser animals, are uniquely able to model how another models the self. The role of mental models for eventually developing artificial intelligence has been stated by Johnson-Laird (1988), among others.

For information systems, Ingwersen (1992; 1996) has stipulated the need for a system designer to model the system contents and the system users; for the indexer to model the user and the author; and for the user to model the system and its content and her information need situation. While the development of usable models remains problematic (even a notion of how to store or represent such models is only minimally formulated), what clearly exists is a need for IR systems which make use of such models for meeting human information needs.

Ingwersen (1992; 1996) includes an extensive review and analysis of IR literature, built on the central theme that cognitive approaches are now becoming the dominant research model both for IR and for the field of information science as a whole. He contrasts cognitive approaches with relevance-based approaches and user-based approaches by pointing out the divergence in focus and goals. The focus of IR, when the cognitive approach is applied, is to engage users in a process of retrieval where non-linear processes effect cognitive states in relatively complex fashions. Compare this to the recall/precision focus of many commercial IR systems, in which single queries are taken as unambiguous representations of information need. The goal of IR from the cognitive viewpoint is to supplement an individual's understanding of the world. This is somewhat inconsistent with user-based approaches, in which the goal orientation is to make use of situational, historical, social, individual, and other factors to help predict the best system response to meet an information need.

Ingwersen's analysis includes use of the terms information space, cognitive space, and problem space in ways which are useful to the current discussion. Information space is, essentially, the content of an IR system including all the relations among stored items and mechanisms for representation and retrieval. Problem space is the domain in which an information need or ASK exists. Ingwersen uses the term "cognitive model" for what we here refer to as cognitive space, although his use has some limitations. The cognitive model is a superset of consciousness, the subconscious, knowledge, memories, and processes for managing all of these components (much as cognitive space is presented at the start of the current work). The limitations in Ingwersen's analysis stem from the fragmentation of the various components of his work: cognitive models should necessarily include models of an information system, the system designer, the authors, contents, etc., not be separate from them.

Ingwersen (1992) concludes that an extended MONSTRAT model must be applied in order to enhance all the various components of information systems (as listed above). However, this is not the outcome of his presentation that makes the most sense! Instead, the logical conclusion is that *the only valid starting point for inquiry related to IR system development must be the cognitive states of system users.*

Ingwersen, like Belkin and others before him, has argued for a cognitive basis for IR, yet turned away from the difficult outcome of the argument. Evidence of this denial may be found in his treatment of the measurement of information and knowledge states of a user. The classic equation for information science is presented by Ingwersen as:

$$\delta \mathbf{I} + \mathbf{K(S)} \rightarrow \mathbf{K(S} + \delta \mathbf{S)}$$

Where information ($\delta\mathbf{I}$) brings about a change in knowledge state **K(S)** such that the new knowledge state is derived from the combination of the old knowledge state with the knowledge state as brought about by the information (p. 31). This treatment is not consistent with a cognitive stance on IR, however: the cognitive stance should not include $\delta\mathbf{I}$ at all, except as an outcome of cognitive processing. Thus,

$$\delta\mathbf{I} \ \mathbf{IFF} \ \delta\mathbf{K(S)}$$

That is, information exists only if a change in knowledge state is brought about. This *strong cognitive stance* on the nature of information is investigated further in the next section.

Ingwersen (1992) provides the most complete treatment of cognitive space as derived from a multi-decade body of literature on IR, AI, and cognitive science. While his conclusions, like all others, are subject to scrutiny, the utility of the analysis for building or evaluating IR systems is clear (regardless of whether one accepts his conclusion of a need for extended MONSTRAT, or the strong cognitive stance presented here).

4. On the Nature of Information and of Cognitive Space

The analysis above has been constructed in order to explore the nature of cognitive space and its utility as a concept with which to build and analyze information systems. The authors and theories under review collectively yield a number of qualities attributable to cognitive space:

- Cognitive space is dynamic, changing as a result of interaction with the environment.
- There are many different processes and systems that contribute to the human experience.
- Cognitive space is closely tied to knowledge, memories, and the human sensorium, and therefore plays a key role in how we perceive and act in the world.
- People are active in the construction and maintenance of their cognitive space. They identify areas of information need (or ASKs) and seek to resolve them.
- Even passive interaction and perception of the environment can yield changes to cognitive space—cognitive space is dynamic in its nature.
- The concepts and relations present in cognitive space are not equally subject to change. People hold some beliefs more strongly than others, and some knowledge is less subject to change.
- Cognitive space is not a metaphorical void in which there are sets of concepts and some sorts of relations among them, with only limited interaction with other aspects of though and perception. Rather, it is continuous and richly connected.
- There is a shared collective component to cognitive space which is produced and maintained constantly through our interaction with other people and the environment.

The picture of cognitive space which emerges has strength of parsimony and intuitiveness. The various authors and theories under review all have different notions of the mechanisms by which cognitive space (and other aspects of the human experience) occur—from this variety, and from the insufficiency of each to adequately describe or predict *all* types of individual and collective human behavior, we must admit that our ability to describe and discuss cognitive space has outpaced our ability to provide a complete picture of how cognitive space actually works!

Yet, there are important empirical or conceptual aspects of each section of the review above which are applicable to explaining how cognitive space works. The work of Dervin and her colleagues has demonstrated a clear ability to generate order from the seeming chaos of information seeking behavior, and to predict with great accuracy the information need that will be experienced by a person in a particular situation. Sense making does little to explain the processes of information seeking behavior, but is extremely effective at predicting that behavior.

Minsky's analysis of the society of mind is far from arbitrary: for many of the areas he proposes for the society, there are definite and significant corresponding areas of research. Topics such as computer vision, balance and walking, pattern recognition, voice recognition and others all have made substantial progress. Almost all of these areas of study for simulation of human-like phenomena using machinery involve a strong commitment to basing their study on the working of actual living creatures. For example, work on computer vision is strongly tied to biological study of the workings of the eye and brain.

The analysis of Woelfel and his colleagues is especially illuminating for this consideration of cognitive space. By applying the physical laws of thermodynamics and motion, Galileo theory and method is able to predict and explain cognitive change as measured by the MDS analysis. Galileo is more readily applied to groups than to individuals, although individual cognitive change may be predicted based on group membership. Empirical evidence from Galileo work indicates clearly that stimuli from the environment bring about cognitive change, but that cognitive change can also result from internal processes.

Based on the proceeding analysis, a strong cognitive stance on the nature of information is proposed here. The proposal is to *consider information as an outcome or product of cognitive change, rather than a cause*.

By approaching information as an outcome, we are able to make maximum use of our understanding of cognitive space for developing information systems. The goal of information system interaction no longer should be, "how do we present the right information?" but instead, "how to we produce the right stimulus in order to bring about the most desirable information in the user?"

To borrow from Woelfel's methodology, a correct analogy for the nature of information from the strong cognitive stance is the nature of heat energy. Heat exists when there is movement in the molecules of some substance. More heat exists with more movement. There is no obtainable state of complete "heatlessness," at which all molecular movement would stop (known as "absolute zero temperature").

As in the heat analogy, information is produced when there is change in cognitive space (a.k.a. cognitive change or cognitive movement). Some change is always taking place; it is an ongoing part of the human experience. Information may be produced as a result of stimuli from the environment, or may be produced as a result of personal thought, introspection, or other processes.

As a component of the society of mind, information produced as a result of changes in cognitive space also fits with human perception and attention. Just as exposure to a document in an unknown language would not be expected to produce much information, exposure to a visual or aural stimulus would also not *necessarily* impinge much on cognitive space—almost like a radio which is not able to receive certain frequencies.

Using this approach, it doesn't make any sense to measure the quantity of information present in, say, a journal article—or even to posit that an article "contains" information. Unlike information theory and other statistical approaches to measuring "information" loss in signals (the theory of Shannon and Weaver, as it has evolved), this strong cognitive stance on human information production in cognitive space tells us that the information produced by exposure to a journal article could be quite different for, say, a college professor versus an undergraduate, or a person with strong background in the article's subject matter rather than a person with little or no background.

Based on this strong cognitive stance, information is something that takes place or is generated in cognitive space. Since cognitive space is empirically shown to have many shared and common aspects (e.g., by the work of Dervin and others, and by our ability to share language, humor, interpretation of the world, etc.), it is possible to predict the extent to which information will be produced as a result of a stimulus—especially for a particular person or group in a particular situation.

This prediction of the generation of information is suggested as the real business of information scientists, and fits extremely well with the theory and research of the field. In addition to describing and representing the information-producing aspects (née "information") present in documents, however, system designers must be required to utilize the cognitive space of the user or user population as a basis for choosing which documents or other items to present.

5. Conclusion

The strong cognitive stance on information production in cognitive space is, perhaps, not the only conclusion that may be drawn from the analysis of cognitive space found above. The nature of cognitive space and the processes by which it comes into being and changes is still, in spite of the analysis, largely mysterious. By utilizing the methods of the researchers mentioned here and others, we are able to glimpse aspects and qualities of cognitive space, and derive satisfaction when actual human behavior matches the predictions of a theory.

Information system designers are required to take aspects of cognitive space into account, but are free to choose among different (and sometimes competing) notions of the nature of information and the likelihood of particular documents producing a desired result. Each of the perspectives presented here, including the strong cognitive stance, offers definite and specific guidance to the information system designer for designing, implementing, and evaluating her wares. By being guided by any or all of these perspectives, we can anticipate systems which are more tightly coupled to actual human experience, and therefore able to be more useful and beneficial to their users.

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February 23, 1998

Dear Dr. Callaos:

In response to your email of 12 February, is it my pleasure to enclose herewith a complete draft paper for consideration for presentation at the SCI ´98/ISAS ´98 conference in Orlando this July.

A fax copy is being sent on 23 February to meet the submission deadline, with paper copies following for overnight delivery to Florida on 24 February. If it would be useful to have electronic copies forwarded by email, please let me know and I will send them.

At 11 pages including references, this is slightly over the page limit for the final papers, but rather than trimming it for submission I wanted to give the referees the opportunity to suggest changes. Thank you for your consideration of my work.

With regards,

Gregory B. Newby