Michael Workman *Editor*

Semantic Web

Implications for Technologies and Business Practices

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Preface

Who can conceive of an organization that does not involve information and systems? Information created and used in organizations reflects all the intellectual property, competitive intelligence, business transactions and records, and other strategic, tactical, and operating data for businesses and people. Regardless of industry, people in organizations today need some understanding of how to utilize these technology and information resources. Nevertheless, information (or cognitive) overload has become such a problem as to become a cliché. This seems even more the case if people work in some form of "knowledge work," a term coined by Peter Drucker referring to one who works primarily with information or one who develops and uses knowledge in their work.

According to the Gartner Group and Aberdeen Research, spending on information systems technologies exceeded the $ 2.26 trillion mark per year worldwide in 2012. Yet research has shown that as much as 25–30 % of information technology goes unused after purchase, and of those technologies used, only a fraction of the available features are utilized. Why is so much money wasted on technologies that are later shelved? Research has shown that the primary reasons for this disuse are that people frequently do too much work for the computer rather than the other way around—this is the so-called ease-of-use problem; and that once people are able to access their information, the information is often irrelevant or obsolete—the so-called usefulness problem.

The wasteful spending on technologies is indicative also of other insidious conditions: technologies are not helping people make better decisions, solve problems better, make better plans, or take better courses of action—leading to unbounded costs associated with lost productivity, lost strategic opportunities, tactical missteps, lost revenues, unnecessary expenses, and the myriad of other problems that result from this waste.

In recent years, there has been an explosion of disruptive technologies. Disruptive technologies are those that radically change a computing paradigm. Without the proper understanding of how to design, implement, or even utilize them, these are likely to fall short of their promise. An area of particular interest for our purposes includes the recent developments in semantic systems and Web 3.0 applications that can respond to situations and environments and events. These technologies do not merely serve up passive displays of information for human consumers to digest, but rather they are intelligent systems that are capable of assisting human beings with the creation of meaning and drawing inferences to improve human performance.

We hope you will enjoy this volume on semantic technologies!

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Chapter 1
Introduction to This Book

Michael Workman

In this book, we hope to raise some provocative questions as much as we want to answer questions about semantic and Web 3.0 technologies. We will begin by introducing cognitive and sociological foundations for why semantic technologies are superior to their predecessors. We then present some contrasting views about specific techniques, followed by some specific examples. We conclude with a look at the state of the art in semantic systems and their implications for businesses and technologies.

We begin a primer on a few key semantic technologies to orient our concepts and vocabulary—i.e., what we mean by semantic systems. Let us start with the notion that semantic systems include dynamic, self-describing models (and a language for constructing these models), semantic resolution among disparate information sources (called ontologies), and the ability to discover these models (Skyttner 1996). We will also broach the idea that semantic systems also subsume social and biologically inspired systems. With these features in place, the addition of semantic brokering and reasoning/inference capabilities may complete a solution for semantic integration, which is a primary goal of many, if not most, of semantic and Web 3.0 technologies.

1.1 Resource Description Framework

There is a trend in moving away from programmed logic to dynamically generated and interpreted logic within the World Wide Web Consortium (W3C) definitions for semantic technologies (Berners-Lee et al. 2001). For example, we are creating new forms of markup, including the Resource Description Framework (RDF; Lassila and Swick 1999), to enrich information and enable intelligent systems. This evolution came about because there is a need for a more advanced approach to information

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and description logics than was possible with HTML or even XML. While RDF is an XML of sorts, that is to say, RDF is based on XML, it is an attempt to make better use of metadata (data about data) by extending into relationships of the data. For example, when you are going to type up a research paper, you might first search the information related to the topic. You might use a search engine which sifts through metadata looking for keywords or combinations of keywords (without regard to the keyword relationships) that might match. RDF, on the other hand, establishes relationships that go beyond keywords and basic knowledge representations (Miller 1998). RDF imposes structure that provides for the expression of relationships needed for the first step toward semantic systems (which is the ability to associate things with their functions or meanings). RDF consists of resources, properties, and statements. A resource is the metadata that defines the given RDF document and is contained at a specified Uniform Resource Identifier (URI). A property is an attribute of the resource such as author or title. A statement consists of the combination of a resource, a property, and its attribute value. These form the “subject,” “predicate,” and “object” of an RDF statement, such as in the RDF statement:

```
<rdf:Descr iption about=’http://www.my.com  /RDF/home.html’>

    <Author>Mike Workman</Author>

    <Home -Page rdf:resource =’http://www.my .com’ />

</rdf:Description>
```

In this example, we can see that a document contains a URI, which is very much like the URL we type into our browsers. It redirects the program reading it to that resource, which will likely be another document.

The assertion is that the document at URI: “http://www.my.com/RDF/home.html” is authored by Mike Workman whose homepage is at URI: http://www.my.com. We could tie more documents together via other URI to form networks of associations. Since a property is an attribute of a resource, any person or even a program can create them, and since RDF statements are essentially a form of XML, they can be dynamically produced (generated) and read (consumed). With RDF statements, we make assertions, such as:

1. Mike Workman is a software engineer.
2. Mike Workman teaches network multimedia.
3. Mike Workman has an office at the Library and Information Sciences (LIS) building.

The dynamic and associative aspects of RDF essentially come from four attributes (Bray 2003): (1) Resources can be defined independently, (2) RDF can be canonized for exchange, (3) RDF enables persistent triples (subject–predicate–object), and (4) RDF enables heritable properties. We can see the flexibility this provides, and it is through this flexibility that the RDF enables universal linkages seen in Fig. 1.1.

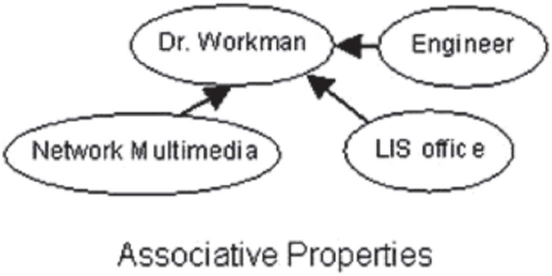

Fig. 1.1 RDF relational associations

1.2 Ontology Markup

It is one thing to infer from relationships, but things fall into classes, and more specifically, objects. From this concept, we may get the sense that RDF can deal fairly well with some aspects of controlled vocabularies such as an antonym–synonym problem, but it does not really help much with the disparate aggregated constituent problem, such as in the case where a "Customer" is not necessarily a "Customer," or a "Teacher" is not a "Teacher" in a processing or even a schematic sense—because their attributes or constituents differ. For example, a set of highly normalized relational database tables that refer to "Teacher" may consist of teacher names, employee numbers, and the atomic pieces that define each teacher, whereas a software object that refers to "Teacher" may consist of not only names but also departments, subject matter taught, rank, and so forth. A reference to one is not necessarily a reference to the other. Equating, differentiating, and resolving these entities go beyond their relationships.

The DARPA Agent Markup Language (DAML) is a markup language that enables computers to draw conclusions based on their constituents because DAML organizes RDF into classes. Thus, in addition to the ability to dynamically specify relationships among entities, descriptive logics such as DAML enable systems to draw conclusions using RDF. If an application is given new information, it can provide additional information based on DAML statements. In other words, DAML statements enable applications to draw conclusions or inferences from other DAML statements.

The Ontology Inference Layer (OIL) is a syntactic encoding language for creating ontologies by allowing humans or software objects (referred to as agents) to markup RDF for knowledge representation and inference. It combines modeling primitives from programming languages with the formal semantics and reasoning services from description logics. Combined DAML+OIL provides the constructs needed to create ontologies (a body of related concepts) and mark up RDF in a machine-readable format, enabling a rich set of object-oriented capabilities (Fresse and Nexis 2002), such as the ability to define not only subclass–superclass relationships but also rules about them such as whether they are disjoint, unions, disjunctions, or have transitivity, along with the imposition of a range of restrictions on when specific relationships are applicable.

Collections of RDF/DAML+OIL can be assembled into even more complex relationships that enable disparate semantic resolution via agents' exchange of ontologies (Fresse and Nexis 2002). This has two dimensions: (1) The unequivocal sharing of semantics so that when the ontology is deployed, it can be interpreted in a consistent manner and (2) when the ontology is viewed by an agent (person or software object) other than the author, it helps to ensure that the intent or meaning of the author is clear. Deriving from these technologies, the Web Ontology Language, or OWL, evolved. The OWL has extended beyond DAML+OIL, and provides a good example of how there is actually a family of web ontology markup languages in the marketplace to choose from.

1.3 Agent Frameworks

Whereas RDF and ontology markup languages and processors have advanced into practice in many systems utilized by businesses, agent frameworks have not yet matured at the same pace. Nevertheless, some of the more recent advances in these technologies have illustrated their potential and viability, particularly in synthetic systems, robotics, and mobile ad hoc networks (Workman et al. 2008). There have been discussions about the merits of agent versus agentless systems in conventional technologies, but in a semantic systems sense, the concept of an agent is much more robust than stationary collector entities that reside on devices, such as in the case of network or application monitors. Semantic agents form a social network and have varying degrees of "problem-solving" capabilities such as setting goals and monitoring progress toward goal completion.

There are many types of agents depending on the roles they may fulfill. For instance, middle agents may act like intermediaries or brokers among systems. They support the flow of information by assisting in locating and connecting the information providers with the information requesters. In other words, they assist in the discovery of ontology models and services based upon a given description. A number of different types of middle agents have shown usefulness in the development of complex distributed multi-agent systems (Murry 1995). Agents may advertise their capabilities with a middle agent, and the method used for discovering and interacting with a service provider may vary depending on the type of middle agent used (cf: Dean et al. 2005). One example is that there may be a middle agent who mediates between requesters and providers by querying services whose advertisements match a requester's service query. The resulting messages are then sent from the provider to the requester via the middle agent.

This contrasts with a matchmaker agent, in which matchmakers do not participate in the agent-to-agent communication process directly; but rather, they match service requests with advertisements, and return these matches to the requesters. In these systems, matchmakers, or sometimes called yellow page agents, process advertisements, and blackboard agents collect requests, and broker agents coordinate both processes. The matchmaker is thus an information agent that helps make connections between various agents that request services and the agents that provide services.

1.4 Looking Forward

We have only begun to introduce key concepts related to our topic, but we needed to introduce some definitions before we delve into more complicated concepts. As people increasingly interact virtually in greater variety and with an expanding set of modalities, we are seeing a concomitant mimicry among the systems people use in the form of socially and biologically inspired technologies, which we will explore further in this book. We are also seeing the emergence of the blending of actualized and virtualized worlds such as in the form of augmented reality. This futuristic journey began with the idea that systems may inherently contain "meaningful" constructs that may eventually be entirely understood by a synthetic system. To date, markup languages can be combined with object-oriented features, which can implement expert capabilities and help us migrate from our current closed-systems approach to computing into an organic, open-system mode. It will be some time yet before many of these capabilities make it into the marketplace and become widely adopted. But as we shall see in the chapters to follow, an inkling of some of these characteristics has already been deployed, and those remaining are following closely on.

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Chapter 2
Semantic Cognition and the Ontological to Epistemic Transformation: Using Technologies to Facilitate Understanding

Michael Workman and Daniel Riding

2.1 Introduction

In this chapter, we present the term “semantic cognition” as a way of introducing semantic systems. Semantic cognition involves the study of top–down, global, and unifying theories that explain observed social cognitive phenomena consistent with known bottom–up neurobiological processes of perception, memory, and language. It forms a foundation for explaining why some technologies work well and others do not. For instance, the problem of information, or cognitive, overload has become all too familiar. For example, cognitive overload can create unneeded stress and hurdles to effective decision-making in the workplace, thus hindering productivity (Adams 2007). Technologies have become quite good in terms of gathering and providing information to human consumers, but they have tended to worsen the information overload problem depending on their construction and use.

The development of technologies informed by semantic cognition emphasizes manipulating form to fit the task and function in terms of the design, development, and implementation, and in the evaluation of technologies relative to goal-oriented outcomes. Form to fit has many implications for how systems will be developed and utilized in the near future to improve human performance.

Structure, Structuration, and Agency

Agency in a structuration sense is anyone who acts within the formalized social structure of an organization. Thus, our use of the term “agency” represents individual behaviors that operate within a broad network of socio-structural influences

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(Chomsky 1996) that can be within or outside the formally defined organizational structures. Bandura et al. (1977) defined this triadic phenomenon as "agentic transactions, where people are producers as well as products of social systems" (p. 1). Agency exists then on three levels: direct personal agency (an individual's actions), proxy agency, which relies on others to act on one's behalf to secure individually desired outcomes, and collective agency, which is exercised through socially coordinative and interdependent effort (Bandura et al. 1977; Chomsky 1996). The notion of agency from this perspective contrasts with nondeterministic (chaotic) and nonrational "natural" processes that create the environments in which people operate either formally or informally (Table 2.1).

The reciprocal relationships between agentic action and social structures are referred to as the "duality of structure" by Giddens (1984). In these terms, structure is defined by the regularity of actions or patterns of behavior in collective social action, which become institutionalized. Agency is the human ability to make rational choices, and to affect others with consequential actions based on those choices that may coincide with or run counter to institutionalized structures.

Structuration, on the other hand, is a dynamic activity that emerges from social interaction. Particularly, social action relies on social structures, and social structures are created by means of social action. The existence of each and the interdependence of social action and social structures can thus be thought of as a constantly evolving dynamic. Thus, structures derive the rules and resources that enable form and substance in social life, but the structures themselves are neither form nor substance. Instead, they exist only in and through the activities of human agents. For example, people use language for communication with one another, and language is defined by the rules and protocols that objectify the concepts that people convey to each other (Chomsky 1996). The syntax structure of language is the arrangement of words in a sentence, and by their relationships of one to another (e.g., subject–predicate noun–verb phrase). The sentence structure establishes a well-defined grammar that people use to communicate.

However, language is also generative and productive and an inherently novel activity, allowing people to create sentences using the syntax rather than to simply memorize and repeat them (Chomsky 1979). In similar fashion, institutionalized

Table 2.1 Agentic attributes

Autonomy	The ability to pursue an individual set of goals and make decisions by monitoring events and changes within one's environment
Proactivity	The ability to take action and make requests of other agents based on one's own set of goals
Reactivity	The ability to take requests from other agents and react to and evaluate external events and adapt one's behavior and make reflexive decisions to carry out the tasks toward goal achievement
Social cooperation	The ability to behave socially, to interact and communicate with other agents
Negotiation	The ability to conduct organized conversations to achieve a degree of cooperation with other agents
Adaptation	The ability to improve performance over time when interacting with the environment in which an agent is embedded

structures regulate agentic behavior, but agents may also disrupt institutionalized structures. The defining features within structuration theory that explain how these processes work are: signification, legitimation, and domination. Signification concerns how meaning is cocreated and interpreted by agents, legitimation encompasses the norms and rules for acceptable behavior, and domination refers to power, influence, and control over resources (Giddens 1984). Collectively, the signification, legitimation, and domination constitute the institutionalized structuration processes. Agentic interaction with these processes creates the communicative structure, authoritative structure, and allocative structure, respectively.

It is important to note that agency behaviors can be modeled in adaptive information systems to act more like human beings so that they can be more compatible with how human beings work and solve problems. For example, modeling these sociobiological artifacts in software have led to the development of epigenetic systems (Bjorklund 1995) in which linear models have become supplanted by more dynamically organized computational models that perform multiple operations simultaneously and interactively with the environment in which it operates (Bandura et al. 1977). The software, or machine, is thus evolving and operating by learning from its environment in an open-ended fashion. Thus, epigenesis from a sociobiological perspective asserts that new structures and functions emerge during the course of developmental interaction between all levels of the agentic biological and environmental conditions (Bjorklund 1995). The notion of agency from this perspective contrasts with nondeterministic (chaotic) and nonrational "natural" processes that create the environments where people are embedded (Beck et al. 1994).

Agency and Agent Systems

Big data analytics draw from mining patterns out of data warehouses or distributed stores. This is a closed system, that is, information is pulled out of an environment and stored away in a large database where it is later examined for patterns by using various analytics. Much may have changed in the dynamic environment since the time the data were extrapolated into the closed system. The closed-system static model of pattern discovery is inherently limited. Moreover, with data warehousing analytics, the user must provide the problem context. By way of using the Web as an analogy, a user must "drive" the search for information with the assistance of a technology such as a crawler or bot. This has widely recognized limitations.

The Web is filled with a sea of electronic texts and images. When you look for something of interest, unless someone provides you with a URL link where you can find relevant material, you will then have to resort to a search engine that gathers up links to everything that it thinks is related to my topic. It is then necessary for you to begin an extensive hunt, sifting through the links looking for possibilities. When you find a page that sounds interesting and begin reading through the material, you will likely discover that it is not what you had in mind. Many of the pages in the Web are cluttered with a multiplicity of subjects, and they are littered with links tempting you to divert your limited attention to another realm, causing you to abandon the original quest in favor of a newly piqued interest (Palmer 2001). Because of their agentic and social attributes, agent-based systems have the potential to help alleviate some of these problems by seeking goals and making evaluations. For example, you may be working in an office in Florida when your boss calls and asks you to attend a meeting with a customer in Dallas to present the company's technical strategy. You then give instructions to an agent to gather intelligence on the customer so that you can frame the presentation for the audience. You may instruct him/her to find published strategies with which to compare so that the customer will see that you have come prepared, and you may also instruct the agent to book the trip, finding the best plane fares for the flights you would want to take, and a hotel near the customer site. To perform these functions, the agent cooperates with other agents (in multi-agent systems, or MAS) to exchange information, resources, and tasks.

The ecosystem in which agents operate is organic. The systems generate descriptions of things and events in the system (called models) and the rules (also in the form of a model) for other agents to use when operating on these models. The systems are not only self-describing, but because the models are dynamically generated within the ecosystem, they are self-defining. Furthermore, models may be advertised and discovered by agents. An agent may even traverse the places where models are advertised and "look" for things and do things. Such a system would be self-renewing, because it can import and export resources. Self-defining, self-renewing, and self-organizing characteristics define an organic system (Bertalanffy 1968).

Goal-Directed Agents

Many systems such as found in many contemporary network and application monitoring use simple stationary agents. In a semantic sense, agents take on more complex behaviors including mobility (Usbeck and Beal 2011). From a semantic perspective, a software agent is an "independent software program with real-time decision-making abilities that acts intelligently and autonomously to deliver useful services" (Agentis Software 2008, p. 1). Goal-directed agents are a special case (cf. BBN Technologies 2004). These agent frameworks are able to adapt in dynamic environments by allowing them to deviate from predefined plans according to their situational awareness (Fig. 2.1).

Goal-directed agents perform a series of steps to carry out a plan, while the agent monitors its environment for substantive changes relative to achieving its defined goals. An agent may choose a different plan, set new goals, and update its "understanding" if it encounters impediments. This ability to "infer" based on changes in the ecosystem is what distinguishes goal-directed agents from their more static predecessors. With goal-directed agents, new plans may be added without affecting the existing plans because plans are independent of one another. Moreover, because agents assemble their execution contexts at run-time, execution paths and error recovery procedures are not required during their design and development (Agentis Software 2008).

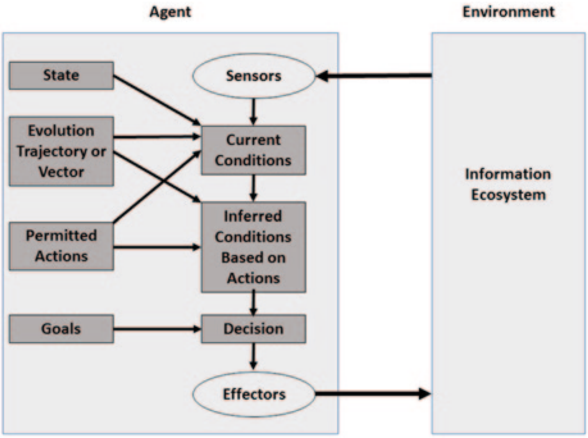

Fig. 2.1 Goal agent architecture

The Problem of Meaning

Building semantic systems stems from human cognition and perception. Thus, a discussion is warranted here to explain what follows.

At the heart of semantic systems is the definition and derivation of meaning. Even with the promise of these more organic technologies, “meaning” is a human construction. If you say, tear, what does this word mean? To answer this question, we need to know the relationship of this word to other words. We need it in context. The word means something different if you say: You have a tear in your shirt versus you have a tear in your eye. One word with two meanings is one level of the semantic problem.

We also have the inverse—many words with one meaning. The antonym and synonym issues are still only half the semantic picture. There are other problems we put in the category of transformational grammar (Chomsky,1979). A door may be opened, or it may be open. We also have the issue of some words operating as verbs in one context and nouns in another—wave, for example—look at the wave versus wave at the crowd. To begin to address this problem, we need some way to describe an entity. The first part of the semantic problem deals with the antonym and synonym problem, and hence the relationships between things are important. However, it is not as simple as that, attributes that define objects can be different, such as with the following:

Teacher: Teacher Name, College, Discipline.
Teacher: Teacher ID, Teaching Philosophy, Degree

The two entities called Teacher consist of different attributes. Some of these attributes may be the same, such as Discipline and Philosophy, but maybe not. A real example is found at the Coca-Cola Corporation where they use independent distributors and bottlers worldwide. Not only do these entities use different languages but also each has different notions of entities as defined by their attributes.

A customer in Bulgaria is not the same as a customer in Montreal. They cannot be equated in business terms.

How might semantic and Web 3.0 technologies help? Most systems are not able to make associations among information because they do not have the structures needed to analyze the relationships among the data; they are only able to process information and perform the functions written into programmatic logic. However, with ontologies, the structures carry part of the semantic association inherent in the data structures themselves. That is, they provide relationships among data that enable systems to make associations from the information based on predetermined rules. The relationships are moved out of the program code and placed inside the documents that programs read and interpret, and reason over. According to Lassila and Swick (1999), "The World Wide Web was originally built for human consumption, and although everything on it is *machine-readable,* this data is not *machine-understandable*." This is among the core of the issues being resolved. To understand how, we need to present an overview of human cognition.

2.2 Cognition Overview

There are (at least) two schools of thought on memory processing and cognition—the Information Processing Approach, where an analogy between the mind and a digital computer is made, and the Ecological Perspective, where the focus is on the dynamics of the environment a person is in, including with machines and people. Informational Processing is conceptualized as where the mind is more "computational" using memory to access memory and form a representation with meaning to a stimulus, whereas the Ecological Perspective relies on a person's perception of the environment around them and their actions form the basis of the conscious mind. The information processing perspective is based on mind–environment dualism, while the ecological perspective is based on mind–environment duality (Cooke et al. 2004).

Memory and Cognition

It is widely recognized that while the capacity of long-term memory is, in theory, virtually unbounded, attentional or working memory is severely limited (Halford et al. 2005). Nevertheless, human brains have the ability to process some kinds of information in simultaneous and nonlinear ways. For example, one may be deeply engrossed in a conversation with her friend and suddenly feel a spider crawling on her hand. Her sensory systems perceive the tiny legs of the spider on her skin and alert her attention; her hypothalamus releases neurochemicals that elicits a fear response to the potential spider bite, she sweeps the spider from her hand and continues her conversation. The person in this situation reacts unconsciously before her schematic knowledge structure stored in memory has processed the behavior (Gioia and Poole 1984). This type of "multiprocessing" indicates that working memory acts as an event receiver, where stimuli compete for "time slices" of attention (Anderson 1983, 2000).

To highlight this point, Dennett (1997) presented the multiple drafts of consciousness theory in which he posited that our conceptions and perceptions of reality are formed in working memory by receiving "snapshots" of the activities processed in different parts of our brains. "Pasting" these snapshots together is somewhat analogous to how photo frames are strung together to make motion pictures (movies). Interestingly, these "realities" are not as contiguous as they might seem in a movie; instead, they are more akin to showing chunks of several different movies in an alternating fashion. However, this does not mean that our attention oscillates between different static frames of apprehension as I might have implied with the simple movie analogy—rather, our brains process information and stimuli with varying degrees of conscious attention in a very fluid and dynamic fashion (Anderson 2000; Bargh and Morsella 2008).

Examining these features reveals the notions of implicit and explicit cognition (Hutchins et al. 2013). Implicit cognition is defined as those processes which are automatic, effortless (in terms of working memory), unconscious, and involuntary, whereas explicit cognition is defined as the intentional use of working memory (Schacter 1995). Given these distinctions, we may also consider "thought" as a memory retrieval process, whereas "thinking" is a creative reconstruction from what has been learned or experienced, or as a process of imagination or concentration (Jensen et al. 1997).

While many functions are specifically performed in well-defined parts of the brain, such as speech and language (most often located in the left hemisphere called Wernicke's and Broca's areas), many portions of the brain are malleable insofar as they "rewire" neural connections, a property known as plasticity. It is intriguing to note that owing to neuroplasticity, the more one attends to a particular stimulus, generally the more readily one comes to recognize or focus on it (Bransford and Johnson 1972). One reason for this is because more frequently used neural pathways are more readily primed, along with their associated cognitive schema (Barnhardt 2005). As Bargh and Morsella (2008) noted, "cognition research on priming and automaticity effects have shown the existence of sophisticated, flexible, and adaptive unconscious behavior guidance systems" (p. 78).

Priming effects and automaticity may be crudely thought of as water following the paths of least resistance—in other words, neural pathways that have been recently or intensively utilized are more easily charged or activated (Craik and Lockhart 1972; Khemlani and Johnson-Laird 2013). Cognitive schema may be thought of as a network of concepts, rules, and protocols (McNally et al. 2001). To illustrate, a procedural schema for ordering food when primed with the word "restaurant" causes people to retrieve a specific set of expectations for their prototype of the restaurant concept. When a prime is modified, such as in the phrase "fast-food restaurant," the schema is also modified (Schacter 1995).

Nevertheless, despite this cognitive flexibility (Shabata and Omura 2012), people tend to lean either toward implicit or explicit cognitive dominance, especially when under time pressure to solve complicated or subjective problems (Barnhardt 2005; Gawronski and Bodenhausen 2006; Richardson-Klavehn et al. 2002). Moreover, since working memory is limited, people develop "habits" because they are cognitively economical (Halford et al. 2005). According to Biel and Dahlstrand (2005), habits derive from deeply embedded and richly encoded thoughts and behaviors built up over time, whereas explicit cognition (including the use of newly learned problem-solving strategies or principles used for making judgment calls) must be remembered and intentionally used.

Moving from the concepts of implicit and explicit cognition, we look at metacognition, which is "knowing what you know." In other words, metacognitive processes create awareness and help coordinate cognition involved in acquiring perceptual, conceptual, and thinking feedback, and monitoring progress toward task solutions (Sternberg 1977). Improving metacognition enables individuals to be better equipped to attend to and interpret relevant information, and use this information to decide how to act and perform effectively (Blume et al. 2013; Engonopoulos et al. 2013). The utilization of metacognitive strategy is also a key difference between expert and novice learners, where the expert learner plans cognitive strategies, monitors them, and will revise strategies to meet goals (Goldstein and Ford 2002). This use of metacognitive strategizing can be useful when dealing with information overload.

Next, when people are inundated with information or when information becomes extremely complex, they experience cognitive information overload (Killmer and Koppel 2002; Watson and Tharp 2013). Since durable information is stored in the form of organized schemata in long-term memory, semantically enriched information helps free up working memory resources and hence allows the limited capacity of working memory and explicit cognition to address anomalies or attend to the more novel features in the information conveyed, and permit cognitive processes to operate that otherwise would overburden working memory (Hutchins et al. 2013; Paas et al. 2003; Seitz 2013; Shabata and Omura 2012). There are emotional and physiological reactivity effects associated with subjective job overload of workers leading to burnout caused by demands made upon them in the work environment and the resources available to them (Shirom 2003).

Information Structure and Semantics

Consider that the bulk of the information with which we are presented and utilize comes to us in a linear form, such as lines on a page that you are reading. One can imagine that this does not capitalize on the brain's natural ability to process information in simultaneous and nonlinear ways. As an example of this linearity, if we asked the question, "What does the word tear mean?" It is unlikely that someone would not be able to tell unless we stated that you have "a tear in your eye" versus you have "a tear in your shirt." We rely on this dependable and relational information structure so that we can "make sense."

In prose, our ability to gain and share knowledge in this way can be described as transformational grammar (Chomsky 1979). Vocabulary rules help to convey semantics because they determine the objective measures by which people draw conclusions and make inferences about ideas. Transformation grammar involves two levels—a deep structure and a surface structure. The deep structure is essentially that of meaning (or intended meaning) encoded with the surface structure, which is that of syntax. To formulate a conception of meaning, or to draw conclusions and make inferences about an intended meaning, the rules and relationships among the words or concepts must be known (Shiffrin and Schneider 1977). Transformational grammar, therefore, is the system of rules and relationships that transform ideas from one structural level to another (Kozma 1991; Trafton and Trickett 2001).

Beyond sense making from information structure, another important aspect of semantic cognition is situational awareness. Endsley et al. (2003) described situational awareness as cognition on three levels: (1) comprehending or perceiving relevant elements in a situation, (2) understanding the meaning of the elements, and (3) the application of the understanding such as to be able to project future states and make inferences. Consequently, situational awareness is a type of "cognitive map" that people develop as they receive information.

While information may be received in many forms (e.g., sound or touch), the majority of information with which people presently work is visual (Card et al. 1999). We have concentrated on visual information so far because this has been the dominant form of information representation in business to date, especially that of written texts. At this juncture, however, we note that visual information has other conveyances, such as with images and drawings. If we consider how these are perceived by our visual sensory systems, and our apprehension of meaning, we might take, for example, a painting we appreciate. The painting conveys information to us in a holistic and simultaneous manner (Langer 1957), but it may leave us with a vague subjective impression of what the painter intended with his or her rendering and what we determined it to mean. The reason why we may not be able to objectively interpret the meaning of the painting is that it lacks transformational grammar. Although some experimentation has been done using graphical linguistics, cuneiforms, symbols, and various forms of isotypes (cf. Lidwell et al. 2003), there has yet to be a consolidation in terms of principles that could enable generalized and objective interpretations.

Indeed, despite a large stream of cognitive and neuroscience theory and literature on visual perception, attention, memory, and linguistics, this is one area where human factors research has traditionally lagged behind the underlying work related to information storage and retrieval theory (Gavrilova and Voinov 2007). This is an interesting issue because underlying storage and retrieval research (cf. McBride 2004) have been utilizing semantic and cognitive theory to drive the development of markup such as RDF and OWL for more than two decades.

The disparity between the semantically rich underlying description logics and the representation of the information models in visual displays of information begs for more theory-driven implementations based on semantic cognition. An interesting feature of these description logics is that the typical linear or hierarchical data