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A man was worried about his 72-year-old father, who had just had a pacemaker implanted. The man believed that his father's condition was serious, despite reassurances from the hospital staff. The man's father had shortness of breath, cardiac arrhythmia, mild congestive heart failure, an enlarged heart, water retention, mild high blood pressure, mild emphysema, and a heart valve replacement 10 years earlier. The combination of all these symptoms and problems seemed ominous. The man coaxed a physician to explain what was going on.

The physician said that the heart valve replacement was irrelevant. Basically, the father had a slightly enlarged heart. That wasn't a big problem except that the area of enlargement had stretched some of the nerves that controlled heart rate; this caused the cardiac arrhythmia. The arrhythmia, in turn, meant that the father's heart was less efficient at maintaining fluid levels, which is often a problem of aging. So, the fluid buildup resulted in mild congestive heart failure and shortness of breath. The mild emphysema didn't help. And that's why they installed the pacemaker. With that simple story, the various data elements fit together in a coherent causal scheme, satisfying the man that this was a treatable problem rather than a cascading breakdown of health.

This story is one of many that researchers use to illustrate the phenomenon of *sensemaking*. Although we can trace this notion to the early 1980s,[1] it has emerged since the 1990s as a subject for organizational research,[2–4] educational research,[5] and symposia on decision making.[6] Sensemaking has become an umbrella term for efforts at building intelligent systems—for example, the research on data fusion and adaptive interfaces.[7,8] Research requests are frequently issued for intelligent systems that will

- automatically fuse massive data into succinct meanings,
- process meaning in contextually relative ways,
- enable humans to achieve insights,
- automatically infer the hypotheses that the human is considering,
- enable people to access others' intuitions, and
- present information in relevant ways and defined in terms of some magically derived model of the human subconscious or its storehouse of tacit knowledge.

These envisioned capabilities appear to be good things to have, and the call for research on such capabilities might serve to throw down a gauntlet and thereby push the envelope of intelligent systems. But we see in various funding opportunities and program descriptions little actual relationship to the notion of sensemaking, especially to empirical-research findings from the field of naturalistic decision making. This essay examines sensemaking from various perspectives to see if we can separate the things that are doable from the things that seem more like pie-in-the-sky.

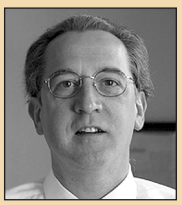
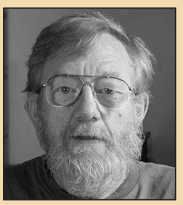
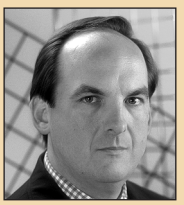
The psychology perspective

First, because sensemaking seems primarily to denote a psychological phenomenon, let's look at the psychology perspective.

Sensemaking has been defined as "how people make sense out of their experience in the world."[9] On the basis of this definition, you might easily conclude that sensemaking is merely a reinvented wheel, expressing concepts that have been common currency in psychology for decades, if not well over a century. Here are five of them.

Creativity

Sensemaking might essentially mean creativity. However, much research on creativity has focused on how peo-

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ple generate novel solutions to individual problems and puzzles,[10] often expressed in terms of transformation within problem state spaces.[11,12] Others rely on the notion of creativity as a measurable individual difference in personality.[13] Even the research on how creativity relates to expertise[14,15] gives no indication that sensemaking might be reduced to a psychological notion of creativity. As most people seem to mean it these days, sensemaking sometimes might involve creativity but it's not the same thing.

Curiosity

Sensemaking might mean curiosity, long referred to as the trigger for "scientific imagination."[16] But in modern psychology, curiosity has typically been invoked to denote just the motivational aspect of exploratory behavior—that is, the physical-perceptual exploration of states of affairs or situations in the perceived environment.[17] As most people seem to mean it, sensemaking involves curiosity but is more than this.

Comprehension

Sensemaking might mean the same thing as the venerable psychological notion of comprehension, but the latter term has historically referred to the understanding of individual stimuli, especially words, sentences, or chunks of prose.[18] Sensemaking is generally understood as the understanding of more complex things—events, in particular.

Mental modeling

Sensemaking might mean the process of creating a mental model.[19,20] A mental model is generally considered a memory representation, with a salient mental-imagery component, depicting states of affairs but linked to or expressed in terms of concepts, principles, and knowledge (for example, a weather forecaster's mental model of the four-dimensional state of the atmosphere). Of all the psychological notions, this one seems closest to what people seem to mean today by sensemaking. Mental models are representations that explain events, not isolated stimuli. Indeed, researchers sometimes use the notion of a conceptual model to define sensemaking.[21]

Situation awareness

However, most discussions consider sensemaking to be even more than this—a process more than a stored memory representation. Psychology's focus has been on achieving a state, some sort of memory representation that constitutes an explanation. Here is the primary difference between sensemaking and situation awareness, although some have defined them as essentially the same.[6] Mica Endsley's work on situation awareness is about the knowledge state that's achieved—either knowledge of current data elements, or inferences drawn from these data, or predictions that can be made using these inferences.[22] In contrast, sensemaking is about the process of achieving these kinds of outcomes, the strategies, and the barriers encountered.

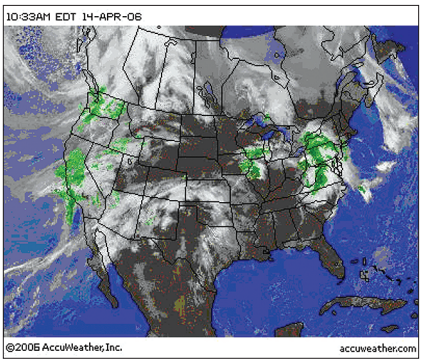

Figure 1. A representative SatRad image from Accuweather (downloaded 14 April 2006 from www.accuweather.com, reproduced with permission).

The verdict

By sensemaking, modern researchers seem to mean something different from creativity, comprehension, curiosity, mental modeling, explanation, or situational awareness, although all these factors or phenomena can be involved in or related to sensemaking. Sensemaking is a motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively.

The perspective of human-centered computing

From the HCC perspective, we don't assume that sensemaking capabilities of the kind we listed in the introduction (for example, data fusion) would actually be useful or usable. Indeed, they might even make people seem less able to act intelligently by limiting their ability to exercise expertise. For instance, fusing data effectively hides information from human analysis, and this cuts against what we know from studies of expert decision making: Experts must be able to explore data, and their analysis can suffer when data are hidden from them in layers of someone else's interpretations.

Let's look at a simple example of fused data. Televised weather forecasts often use a SatRad (satellite-radar) display, such as the one in figure 1. SatRad images are perhaps adequate to convey to the public where rain might occur, but if you ask a forecaster to generate a forecast based on such an image, the most likely response would be, "Show me the data." Why? For one thing, forecasting relies on many radar data types, and the "Rad" in SatRad is just one—base reflectivity.[23] Also, the satellite image—those graphical features that appear to represent clouds—isn't in fact a satellite picture of clouds; it's an infrared radiometric image, which carries particular nuances for correct interpretation. The fused data don't provide nearly enough information to support forecasting beyond mere guesswork. The task of building a rich mental model of atmospheric dynamics on the basis of fused data would trigger in the forecaster little more than frustration.

The sensemaking capabilities that people have envisioned have another potential problem. The technologies that spew out abductive inferences would almost certainly trigger some surprises, when the machine acts mysteriously without making its inner workings or intent apparent to the human. Certainly, data fusion algorithms can reduce information overload, but they also pose challenges to sensemaking if the human can't form an accurate mental model of the machine, to understand why and how the algorithms are doing what they're doing. The human will probably be multitasking. Managing and concentrating his or her attention will suffer when the machine is in the driver's seat. Unless the person has already developed trust in the technology and knows why the machine thinks something is important, the machine might be more of a nuisance than an aid.[24]

So, the verdict is this: For those who ask for the world, and those who promise it, caveat emptor.

The perspective of naturalistic decision making

The NDM perspective offers a way of finding some interesting questions about

sensemaking. Perhaps even more important, it provides an empirical base that anchors the theoretical ruminations in concrete examples and findings. These, in turn, serve as a rationale for questioning some assumptions that underlie the drive to make intelligent sensemaking systems.

NDM research has used methods of cognitive task analysis in many studies of how domain practitioners make complex decisions in dynamic environments.[25–27] This research has yielded a large corpus of observations and cases in which phenomena might be ascribed to sensemaking. We began this essay with one such case, an explanation of the hospitalized father's symptoms. This and many other incidents[24,28,29] illustrate that sensemaking serves several functions:

- It satisfies a need or drive to comprehend.
- It helps us test and improve the plausibility of our explanations and explain apparent anomalies. Whether an explanation makes sense depends on the person who's doing the sensemaking. The property of "being an explanation" isn't a property of statements but an interaction of people, situations, and knowledge.
- It's often a retrospective analysis of events. It clarifies the past but doesn't make it transparent (that is, completely understood).
- It anticipates the future. This makes action possible, though uncertain. It helps us muster resources, anticipate difficulties, notice problems, and realize concerns.
- It isn't the choice of an explanation but a process of deliberating over alternative plausible explanations.
- It guides the exploration of information.
- It's often a social activity that promotes the achievement of common ground. It isn't just an individual activity.

The NDM research strongly suggests that several assumptions about sensemaking don't hold up under empirical scrutiny. Here we list and refute some of the myths.

Myth: Data fusion and automated hypothesis generation aid sensemaking

Research shows that when human decision makers are put in the position of passively receiving interpretations, they're less apt to notice emergent problems.[30]

Myth: Sensemaking is simply connecting the dots

We've often seen this metaphorical description of cognitive work, especially in reference to the intelligence analyst's job. It trivializes cognitive work. It misses the skill needed to identify what counts as a dot in the first place. Of course relating dots is critical, but the analyst must also determine which dots are transient signals and which are false signals that should be ignored.

Myth: More information leads to better sensemaking

Researchers have shown that more information improves performance up to a point, but after that point additional information isn't helpful and can sometimes even degrade performance.[31,32] Confidence continues to increase with additional information so that people become increasingly overconfident rather than increasingly correct.

Sensemaking doesn't always have clear beginning and ending points. The simplified waterfall model of cognition runs counter to empirical evidence about expert decision making.

Myth: It's important to keep an open mind

Jennifer Rudolph presented anesthesiologists with a "garden path" problem—an initial setup that suggests one hypothesis, followed by a dribbling of contrary cues that indicate a different hypothesis.[30] The paradigm measures how long it takes for people to get off the garden path. Rudolph found that people who jumped to an early conclusion and fixated on it showed the worst performance, as she expected. But the participants who kept an open mind and refused to speculate were just mediocre, and not the best, which was contrary to Rudolph's hypothesis. The best participants were the ones who jumped to an early speculation but then deliberately tested it. Their initial hypothesis gave them a basis for seeking data that would be diagnostic. This approach was more useful than the "open mind" approach that's basically a passive mode of receiving data without thinking hard about them.

Myth: Biases are inescapable and prevent reliable sensemaking

This is the view posited by the "heuristics and biases" school of laboratory-based decision research.[33] However, W. Sieck and we three authors have recently completed research that shows this view's limitations in the analysis of real-world, expert decision making (*The Theory of the Handicapped Mind: Revisiting the Psychology of Intelligence Analysts*, to be published by the Institute for Human and Machine Cognition, 2006, is available from Robert Hoffman upon request). The so-called biases are mostly found in laboratory studies using artificial puzzle tasks and college freshmen as subjects, conditions that minimize expertise and context. In natural settings, biases can disappear or be greatly reduced.

Myth: Sensemaking follows the waterfall model of how data lead to understanding

This myth is that sensemaking follows the progression data → information → knowledge → understanding.[34]

Naive information-processing accounts assume that primitive data or isolated cues are successively massaged by inferential operations until they emerge from the other end as knowledge or wisdom. This is misleading in a number of ways. For instance, sensemaking doesn't always have clear beginning and ending points. The simplified waterfall model of cognition runs counter to empirical evidence about expert decision making, and it runs counter to evidence showing that data themselves must be constructed.

The verdict

All this suggests that the phenomena of sensemaking remain ripe for further empirical investigation and that the common view of sensemaking might suffer from the tendency toward reductive explanation.[35] What might be of help, therefore, would be a richer theory of sensemaking, one that gives shape to all the features of sensemaking listed earlier.

In the next essay in this department, we will present a theory of sensemaking that integrates our empirical understanding and points in new directions for the creation of intelligent systems. ■

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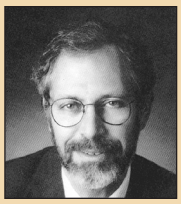

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