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How to Make Sense of Weak Signals

There's no sense in denying it: interpreting weak signals into useful decision making takes time and focus. These three stages can help you see the periphery — and act on it — much more clearly.

BY PAUL J.H. SCHOEMAKER AND GEORGE S. DAY

THE LEADING QUESTION

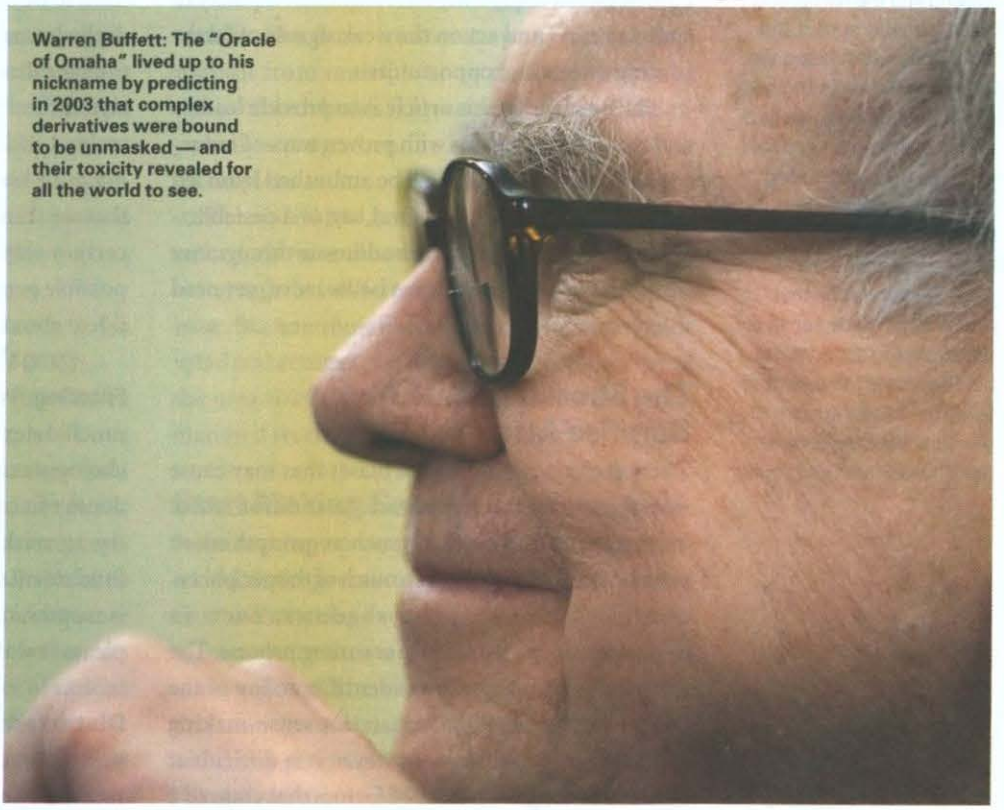
How can managers develop their peripheral vision to see what's ahead more sharply?

FINDINGS

- **Managers who can identify and minimize both their personal and organizational biases are less likely to get blindsided.**
- **Catching and capturing distant threats and opportunities means applying different search methods — and looking for overlapping results.**
- **Teasing out the implications of any finding requires fitting it into different frameworks.**

"When people stumble onto the truth they usually pick themselves up and hurry about their business." — attributed to Winston Churchill

IT'S THE QUESTION everyone wants answered: Why did so many smart people miss the signs of the collapse of the subprime market? As early as 2001, there were many danger signals about the impending housing bubble and the rampant use of derivatives. Yet these signals were largely ignored by such financial players as Northern Rock, Countrywide, Bear Stearns, Lehman Brothers and Merrill Lynch until they all had to face the music harshly and abruptly. Some players were more prescient, however, and sensed as well as acted on the early warning signals. In 2003, investment guru Warren Buffett foresaw that complex derivatives would multiply and mutate until "some event makes their toxicity clear." In 2002, he derided derivatives as financial weapons of mass destruction. Likewise, Edward Gramlich, a governor of the Federal Reserve, warned in 2001 about a new breed of lenders luring buyers with poor credit records into mortgages they could not afford.[1]



Warren Buffett: The "Oracle of Omaha" lived up to his nickname by predicting in 2003 that complex derivatives were bound to be unmasked — and their toxicity revealed for all the world to see.

AP IMAGES

Some business leaders also noticed. Hedge-fund honcho John Paulson spotted "overvalued" credit markets in 2006 and made $15 billion in 2007 by shorting subprime. In July 2006, the chief U.S. economist at The Goldman Sachs Group Inc. warned that "nominal U.S. home prices may be headed for an outright decline in 2007. It would be the first decline in national home prices ever recorded, at least in nominal terms." And in early 2007, his colleague further warned that "there are signals of a decrease in mortgage lending criteria and initial

signals of financial troubles from subprime lenders."[2] Likewise, the board of the Dutch bank ABN AMRO Holding N.V. recognized the looming problems facing the banking sector, and sold itself. Shareholders did very well, collecting about $100 billion before it all fell apart, with Fortis SA/NV and others in the syndicate in ruin.[3]

So, what separates the prescient few from the hapless horde? Did the siren call of outsize profits and bonuses, coupled with the delusional promises of manageable risk, dull the senses? Was the ability to see sooner and more clearly compromised by information overload, organizational filters and cognitive biases that afflict sense making in all organizations? Economist Robert Shiller of Yale University, a leading housing expert, recently invoked "groupthink" to explain why the Federal Reserve didn't take the early warning signs of a looming housing bubble more seriously.[4]

All managers are susceptible to the distortions and biases we saw in the credit crunch of 2008. Organizations get blindsided not so much because decision makers aren't seeing signals, but because they jump to the most convenient or plausible conclusion. Our own research suggest that fewer than 20% of global companies have sufficient capacity to spot, interpret and act on the weak signals of forthcoming threats and opportunities.

The purpose of this article is to provide leaders and management teams with proven ways of reducing the chance that they will be ambushed from left or right field by an upstart rival, say, or a destabilizing technology. Our approach addresses the *cognitive* biases organizations may not be aware of, yet need to overcome.

The Shocking Truth About Surprise Attacks

There are various *individual* biases that may cause managers to be taken unaware. In addition, there are *organizational* biases — such as groupthink or polarization — that may keep much of the periphery-dwelling enemy in the shadows, even in organizations with an active scanning process. The decision-making literature identifies many of the human weaknesses that impair our sense-making skills.[5] Even for scholars, however, it is difficult at times to untangle the knot of factors that clogged a decision-making process. For example, academics have attributed NASA's ill-fated decision to launch the space shuttle Challenger in 1986 — despite multiple warnings from its own engineers about risky O-ring seals — to multiple causes. Among them: incomplete data analysis by key engineers (a cognitive failure); stress-induced groupthink — a bias that values consensus above independent thinking — caused by deadlines and isolation (a group-dynamic explanation); and organizational values that gradually normalized danger beyond the point of prudence (a cultural or institutional explanation).[6]

Once managers lock in on a certain picture, they will often reshape reality to fit into that familiar frame.[7] (See "Missed Signals in Pearl Harbor.") Humans tend to judge too quickly when presented with ambiguous data; we have to work extra hard to consider less familiar scenarios.

Whenever multiple pieces of evidence point in opposite directions, or when crucial information is missing, our minds naturally shape the facts to fit our preconceptions.

Personal Biases: An Objective View

Although complete objectivity is elusive, managers need to be aware of well-established traps that underlie human inference and judgment. The major ones are described below in terms of how information is filtered, interpreted and often bolstered by seeking additional information aimed at confirming prior leanings.[8] The net effect of these biases is that we frame a complex or ambiguous issue in a certain way — without fully appreciating other possible perspectives — and then become overconfident about that particular view.

Filtering. What we actually pay attention to is very much determined by what we expect to see. Psychologists call this *selective perception*. If something doesn't fit our mental model, we often distort reality to make it fit rather than challenge our fundamental assumptions. A related phenomenon is *suppression* or the refusal to acknowledge an unpleasant reality because it is too discordant.

Distorted Inference. Whatever information passes through our cognitive and emotional filters may be subject to further distortion. One well-

GETTY IMAGES

MISSED SIGNALS IN PEARL HARBOR

On the morning of December 7, 1941, the captain of the destroyer USS Ward heard muffled explosions coming from Pearl Harbor on the mainland. This captain had dropped depth charges on an enemy submarine moving into the harbor and had apparently sunk it. Yet when the captain heard the explosions while sailing back to port, he turned to his lieutenant commander and said, "I guess they are blasting the new road from Pearl Harbor to Honolulu." Despite his unusual encounter with a foreign submarine that morning, he made sense of the exploding sound using his peacetime mind-set and failed to notice the signs of the first hostilities between the United States and Japan.

known bias is *rationalization*: interpreting evidence in a way that sustains a desired belief. We fall victim to this when trying to shift blame for a mistake we made to someone else or to external circumstances. *Wishful thinking* leads us to see the world only in a pleasing way, denying subtle evidence that a child is abusing drugs or a spouse is being unfaithful. Another common interpretation bias is *egocentrism*, according to which we overemphasize our own role in the events we seek to explain. This self-serving tendency is related to the *fundamental attribution* bias, which causes us to ascribe more importance to our own actions than to those of others or the environment. We often view our organization as a more central actor than it really is.

Bolstering. Not only do we heavily filter the limited information that we pay attention to, but also we may seek to bolster our case by searching for additional evidence that confirms our view. We might disproportionately talk to people who already agree with us. Or we may actively look for new evidence that confirms our perspective, rather than pursuing a more balanced search strategy. Over time, our opinions may become frozen and our attitudes hardened as we immunize ourselves from contradictory evidence. Indeed, we may even engage in *selective memory* and forget those inconvenient facts that don't fit the overall picture. The *hindsight bias* similarly distorts our memories such that our original doubts are erased. A vicious circle is created in which we exacerbate the earlier biases and get trapped in a self-sealing echo chamber.

Organizational Bias: Getting Along, Getting It Wrong

In addition to our personal biases, we function in organizations as well and may end up suffering from what social psychologist Irving Janis termed groupthink.[9] In principle, groups should be better than individuals at detecting changes and responding to them. But often a group can fall victim to narrow-minded analysis, tunnel vision, a false sense of consensus and poor information gathering, resulting in groupthink. The true relevance of various snippets of information often can be fully appreciated only when they are debated with others and merged into a larger mosaic.

The organizational problems caused by dispersed memory and varying perceptions can only be overcome when information flows freely across departmental boundaries.[10] During the five months preceding the terrorist attacks of September 11, 2001, for example, the U.S. Federal Aviation Administration received a total of 105 intelligence reports, in which Osama bin Laden or Al Qaeda were mentioned 52 times.[11] These reports, from the CIA, FBI and U.S. State Department, were streaming into various parts of the government bureaucracy, which did not have the necessary means to make sense of it all. Some signals were dismissed at the local level and simply not transmitted; some were shared as fragments that remained unconnected to other pieces of the puzzle. The end result was that the full magnitude of the terrorist threat facing the United States was not seen in time, even when the signals were there.

Organizational sense making occurs in a complex social environment in which people are not just sensitive to what is being said, but also to who is speaking. We judge both the signal and the source when we assess the meaning of information. Source credibility is influenced by many factors, including status, past experience, politics and the like. Since most managers receive information from multiple sources, they need to be aware of such biases. These social biases will be especially strong when the information is weak or incomplete.

The individual and organizational biases discussed above underscore why it is important to bring together different perspectives on the same issue. But *how* these different perspectives are cultivated and connected will greatly affect the ability of the organization to make sense of the weak information it receives.[12]

Start Making Sense

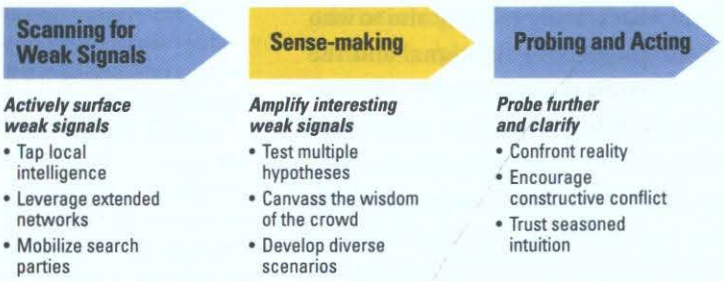
Sense making or interpretation is usually the weakest link in the process of capturing weak signals and eventually making a sound decision. How can management learn to overcome biases to improve their sense making? There are nine proven approaches that managers can use actively to reveal, amplify and clarify potentially important weak signals. (See "Finding a Purpose of Sense," p. 84.)

Actively Reveal Weak Signals

1. Tap local intelligence. Insects use a compound lens system, where most of what they see and notice occurs in the eye itself as opposed to in the brain. They rely on "localized intelligence" at the level of each eyelet and respond accordingly. Likewise, organizations may wish to drive more of their sense making to local levels. Terrorist networks have demonstrated the deadly power and resiliency of such an approach, using nearly autonomous cells that see and think locally. Or, in a more positive vein, Linux and the open-source movement have used local design to build an ongoing global software project.[13] From fighter plane cockpits to nuclear power plant control rooms, the key to safety and reliability is to spot problems early and share them among well-trained personnel. This requires procedures for real-time cognition and constrained improvisation to bring about flexibility and promptness in highly complex, volatile environments. Accessing distributed intelligence takes a culture of alertness and information sharing across multiple social networks.[14]

FINDING A PURPOSE OF SENSE

There's no sense in denying it: interpreting weak signals into useful decision-making takes time and focus. These three stages can help you see what's on the periphery — and act with much more confidence.



2. Leverage extended networks. A valuable but frequently overlooked way actively to reveal weak signals is for executives to query their extended networks to partners, suppliers, customers and others in the company's ecosystem. The common element of all these networks is that they extend the eyes and ears of the company. Different networks tap different zones of the periphery in diverse ways. For example, the research and development departments of Royal Philips Electronics N.V. and General Electric Co. were greatly helped in their early days by being deeply embedded in external government, academia and customer networks, as well as connected to other parts of the organization internally.[15] Similar results were found in a historical study of Merck & Co. Inc., showing how its innovations in biological compounds were related to a "series of complex, evolving networks of scientific, governmental and medical institutions."[16] One consequence of greater organizational participation in extended networks — where many nodes in the network are connected to other networks — is a rapid increase in the number of weak signals received. This problem is intensified within Internet-enabled networks, which virtually eliminate signal transmission time and cost. Thus, managers must be selective about which signals to pay attention to and stay within the boundaries of the company's absorption capacity.

3. Mobilize search parties. Senior leaders can identify weak signal areas that merit separate task forces to canvass further. For example, IBM Corp. has an ongoing capability called "Crow's Nest" to scan specific zones of the periphery and share insights with top management. The zones include time compression, customer diversity, globalization and networks. The responsibility of the group is to rise above functional and product blinders, like a "crow's nest" on a ship, where lookouts watch for new land, pirates and dangerous reefs ahead.

Scanning activities are most valuable when used in combination. For example, the CIA has brought together a crow's nest-type group and a venture fund to find and assess emerging technologies that could be used to fight terrorism. The agency tasked a sensing group with identifying and assessing these technologies. The primary activity of the sensing group is to be the link between the agency and In-Q-Tel Inc., an internal but separate venture fund that invests in startups with technologies that could address an agency priority. Because In-Q-Tel has access to the deal streams of tier 1 venture capital companies, it allows the CIA to get involved early, when the technology can be shaped to address an agency problem.

Amplifying Interesting Signals

4. Test multiple hypotheses. Organizational sense making is usually driven toward a single interpretation, so new data are force-fit into the existing mental model.[17] Managers often have limited tolerance for ambiguity and may be reluctant to devote additional time to develop alternative hypotheses. However, organizations need competing hypotheses to escape the trap of getting stuck on a simple, single view that is wrong. The British Armed Forces and other organizations deploy so-called red teams to accomplish this. The red team is a parallel task force, made up of senior leaders and support staff, whose only mission is to collect and synthesize information to prove that the current plan is wrong and needs to be changed.[18] This team plays the role of the loyal opposition, in the spirit of Alexander the Great, who would periodically ask himself how much evidence it would take for him to abandon the current plan.

As was recognized so painfully after the initial, short-lived U.S. military victory in Iraq, such contrarian information is usually dispersed, unreliable and ambiguous at first. Unless a concerted effort is made by credible and trusted parties to show that the combined evidence from many sources calls for a change of course, leaders may pursue a flawed strategy for too long. The red team approach requires a judicious balance between the doubt necessary to challenge false assumptions and the conviction or courage needed to pursue a bold course of action in the face of challenge and opposition. This balance can occur only if the underlying theme is that strategic surprise is inevitable and midcourse corrections are often necessary when facing the unknown. In the pithy phrase of Prussian General Helmuth von Moltke, "No plan survives contact with the enemy."

5. Canvass the wisdom of the crowd. To handle the dangers of groupthink or the problem of distributed intelligence (where key information is dispersed around the organization), managers may wish to pay more attention to the grapevine. James Surowiecki, author of *The Wisdom of Crowds*, summarizes research showing that groups or markets often make far better judgments than individuals. This is particularly true if companies can create forecasting methods (such as Delphi polling) to pool the collective wisdom of an organization without fostering undue conformity. Information flows quickly through the grapevine when Big Brother is not watching. One way to avoid collective myopia is to create anonymous opinion markets. For example, in the 1990s, Hewlett-Packard Co. asked employees to participate in a newly created opinion market to forecast its sales. Employees would bet in this market at lunch or in the evenings, revealing through their investments where they thought the sales trend was headed. This market's forecast beat traditional company forecasts 75% of the time. More recently, a division of Eli Lilly and Co. asked employees to assess whether drug candidates would be approved by the FDA based on profiles and experimental data, and the internal company market correctly identified the winners from a set of six candidates.[19]

6. Develop diverse scenarios. Unfortunately, no method is perfect, and uncertainty can never be fully tamed or conquered. The consensus can be badly mistaken, as Charles Mackay vividly chronicled in his classic 1841 book, *Extraordinary Popular Delusions and the Madness of Crowds*. To challenge the dominant view in your organization, it may be wise to create multiple scenarios about the issues under debate. For example, when a Houston credit union was going gangbusters thanks to Enron Corp.'s meteoric rise, one of our colleagues asked senior managers to imagine a scenario where they could no longer rely on Enron for growth and deposits. At first, there was reluctance to develop such an unrealistic and negative view, especially because Enron was the company's single corporate sponsor. But then some interesting scenarios emerged, ranging from an Enron takeover to more dire scenarios involving trouble for either Enron or the credit union. Later, when Enron suddenly collapsed, the credit union was saved — against the odds, according to regulators — because managers had taken pragmatic actions to be less dependent on Enron.[20] They had launched their own e-mail system to communicate with members rather than using Enron's system. And they had opened branches outside the Enron building and started to admit non-Enron employees into the credit union.

By considering multiple scenarios at the same time, the organization can keep from being locked

into one view of what future might emerge and yet share a common set of frameworks for discussing new signals.[21] Royal Dutch Shell PLC, which pioneered scenario planning in the corporate sector, viewed it as "the gentle art of re-perceiving."[22] The aim of scenario planning at Shell was not so much to plan as to challenge people's mental models. Scenario planning systematizes the hunt for weak signals that may foreshadow fundamental shifts in the marketplace and society at large — scenarios seek to magnify "postcards from the edge" so that they are readable by more eyes.

WHAT IS A WEAK SIGNAL?

A seemingly random or disconnected piece of information that at first appears to be background noise but can be recognized as part of a significant pattern by viewing it through a different frame or connecting it with other pieces of information.

Probing and Clarifying

7. Seek new information to "confront reality." As Larry Bossidy and Ram Charan emphasize in their book *Confronting Reality*, the greatest business failures are usually not due to poor management but rather reflect failure to "confront reality."[23] Bossidy and Charan write about how data-storage company EMC Corp. missed key changes in its environment that caused a rapid decline in sales in 2001. EMC's sales force, speaking mostly with CIOs, was confident that orders were only being delayed. They interpreted the downturn as a temporary blip. But when Joe Tucci was named CEO in early 2001, he began speaking to CEOs and CFOs at customer companies and found that they were not interested in paying a premium for top performance. Also, they wanted software that wasn't proprietary, since IBM and Hitachi Ltd. were selling machines comparable to EMC's at a lower price. As EMC's market share slipped, Tucci rapidly transformed EMC's business model to focus more on software and services than on hardware, which was becoming commoditized. Once Tucci recognized the new reality, he understood how the company needed to transform.

8. Encourage constructive conflict. A statue in Helsinki, honoring former Finland president J.K. Paasikivi (1870-1956), is engraved with his motto that "All wisdom starts by recognizing the facts." This is especially difficult when not all the facts are known and subject to interpretation. Wisdom requires constructive conflict to ascertain and interpret the facts as they are. But the conflict must be among ideas, not people, and remain within reason. Several academic studies show that *moderate* conflict, as opposed to little or extreme conflict, leads to the best decisions.[24] This results in better intelligence gathering, a wider exploration of options and a deeper examination of the issues. Unfortunately, the opposite often happens, as one insider at Merrill Lynch & Co. Inc. observed about the leadership team under CEO Stanley O'Neal: "There was no dissent. So, information never really traveled."[25] Leaders can play a key role in managing conflict well; they must allow peripheral observations by team members to enter the discussion.

9. Trust seasoned intuition. Experienced managers often possess far more knowledge than they realize, especially when operating within their domains of expertise. If so, they should learn when and how to trust their hunches. Scientist Gary Klein has studied the power of intuition in fast-moving environments such as firefighting, medical emergencies and military combat.[26] In one study he found that experienced nurses picked up the onset of septic shock in premature infants at least a day before the textbook symptoms appeared and a blood test could confirm the presence of the deadly bacterium. These nurses had learned to be sensitive to weak signals even if the cues varied and the symptoms were not strong. It takes many years of experience, with good feedback, to develop reliable intuition. But once it has been honed, intuitive hunches should be viewed as valuable inputs, along with more analytical ones, for the judgment process.

Broadening Your Perspective

Just as having two eyes allows humans to use triangulation and parallax for depth perception, organizations should use *multiple* perspectives to provide greater peripheral vision. Unlike humans, organizations can draw upon more than two eyes to make sense of what they're seeing. Each single view may have its biases, but several views together allow organizations to see what's really going on and identify new opportunities.

When General Motors Corp. developed OnStar, it drew on expertise in both technology and marketing to identify an emerging market opportunity. The carmaker launched the OnStar service in its 1997 Cadillac line, using "telematics," the integration of wireless communications, vehicle monitoring sys-

tems and location devices. This new venture was far out on the periphery of the automobile market. OnStar had nothing to do with automobile design and production. Telematics had little to do with price, reliability or comfort — the industry's traditional bases of competition. Finally, the market was minuscule. In the early days, OnStar set a goal of bringing in 50 new customers a day in an organization that's used to counting its buyers by the millions.

How did General Motors manage to get this peripheral opportunity rolling? GM's acquisition of Hughes Electronics Corp. (and later EDS Corp.) gave it an early window on telematics technology, and the company had reason to believe that there was a market for it. In 1995, GM had commissioned a study to look at the key factors influencing consumers' decisions to purchase an automobile. The study revealed 26 factors, which were ranked according to their importance to customers' current satisfaction.[27] GM found that while customers were very satisfied with how its products met their need for "mobility," four factors revealed important unmet consumer needs: (1) personal attention, (2) limited time and energy, (3) privacy and (4) personal safety.[28] With insights into the desire of customers for personal attention and safety, as well as an understanding of the emerging technology, GM managers were able to spot an opportunity at the intersection. By 2004, OnStar controlled 70% of the market with 2.5 million subscribers, generating an estimated $1 billion in revenue.

Seeing the Biggest Picture Possible

No single technique will suffice in revealing the whole picture, since all methods are flawed or limited in some important respect. Managers seeking to understand an emerging technology might use analogies to markets for technologies with similar characteristics. But these analogies distort, because the situations may not be comparable in critical but unknown respects. A combination of methods is ideal.

Deploy Multiple Lenses. One way to systematize the triangulation process is to look at weak signals through various scenario lenses. More than a decade ago, we worked with a major U.S. newspaper company that used scenario planning to look at a single technological innovation from different perspectives. Xerox Corp. had just introduced a new service to deliver customized newspapers electronically to hotels and other locations, allowing users to print out tailor-made content. Travelers to foreign cities, for example, could get their local news delivered or read the leading national newspaper in their native language.[29]

How important was this signal? Would it mean that hotel guests would never again hear the familiar thump of a newspaper outside their doors, or would it be a nonstarter? It depends on the scenario. In a scenario of "business as usual," this new service would represent a niche market (the traveler's market) and a welcome alternative channel of distribution besides the physical delivery of newspapers. It might create new opportunities for newspapers to move beyond their natural geographic area as well as enhancing customer loyalty. In another scenario, called "cybermedia," where electronic channels would be adopted rapidly, this initial foray into customized printing in hotels might lead to customized home printing of newspapers. Such a development could render the company's physical assets (such as expensive printing presses) obsolete.

Moderate conflict, as opposed to little or extreme conflict, leads to the best decisions. But the conflict must be among ideas, not people.

By looking at this single weak signal through multiple lenses, the managers were better able to explore its potential implications. Considering the high ambiguity surrounding the signal, the company decided to track the development of remote electronic printing of newspapers. While such scenario-based analysis doesn't eliminate the uncertainty about either the development of the technology or consumer acceptance, it can help managers make better sense when one small piece of information is added to the puzzle (such as Xerox's minor announcement about remote printing options).

Talk to Customers *and* Competitors. Companies often suffer from focusing too narrowly on either customers or competitors, rather than looking at both. An exclusive focus on one or the other creates dangerous blind spots.[30]

By looking closely at its customers *and* competitors, a company that owned a major carpet manufacturing business forced its management team to face up to so many unpleasant realities that it walked away from the business.

These are just a few examples of how multiple perspectives and methods can aid in the interpretation of weak signals from the periphery. Overlaps in scanning may seem inefficient, but they serve an important purpose. They verify a weak signal's strategic import, and help to compensate for known deficiencies in our individual and collective vision.

Conclusions

There is a major difference between taking in signals and realizing what they mean. Managers as well as organizations tend to see the world in a certain way and confuse their mental maps with the territory. Weak signals that don't fit are often ignored, distorted or dismissed, leaving the company exposed.

In any given week — especially lately — the popular press is full of examples of managers missing weak signals. The major problem is that managers are insufficiently aware of cognitive and emotional biases that can cloud their judgment when interpreting weak signals. When ambiguity is high, we can easily torture the weak data until it confesses to whatever we want to believe. Countering these insidious tendencies requires leadership as well as the mastery of various tools to combat the pernicious filters that obscure and distort important weak signals. In a fast-moving marketplace, none of us can afford to miss what we are seeing.

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REFERENCES

1. E.L. Andrews, "Fed Shrugged as Subprime Crisis Spread," New York Times, Dec. 18, 2007; P. Barrett, "Wall Street Staggers," Business Week, Sept. 29, 2008, 28-31; and N.D. Schwartz and V. Bajaj, "How Missed Signs Contributed to a Mortgage Meltdown," New York Times, Aug. 19, 2007.

2. These and other warnings were sounded by Jan Hatzius, chief U.S. economist at Goldman Sachs, July 30, 2006; Dan Sparks, mortgage department, Goldman Sachs, The Times, Jan. 2007; and again by Jan Hatzius on Feb. 12, 2007, at a Goldman Sachs housing conference.

3. Board member interview with authors; see also a detailed account in Dutch by P. Battes and P. Elshout, "De val van ABN AMRO" (Amsterdam: Business Contact, 2008).

4. R.J. Shiller, "Challenging the Crowd in Whispers, Not Shouts," New York Times, Nov. 2, 2008, p. 5.

5. For a managerial overview of the extensive field of decision making, see J.E. Russo and P.J.H. Schoemaker, "Winning Decisions" (New York: Doubleday Publishing Co., 2001).

6. The space shuttle data oversights are discussed in S.R. Dalal, E.B. Fowlkes and B. Hoadley, "Risk Analysis of the Space Shuttle: Pre-Challenger Prediction of Failure," Journal of the American Statistical Association 84, no. 408 (December 1989): 945-957; and E.R. Tufte, chap. 2 in "Visual and Statistical Thinking: Displays of Evidence for Making Decisions" (Cheshire, Connecticut: Graphics Press, 1997). The groupthink explanation of the Challenger case, and the associated tendency toward excessive risk taking, are examined in J.K. Esser and J.S. Lindoerfer, "Groupthink and the Space Shuttle Challenger Accident: Toward a Quantitative Case Analysis," Journal of Behavioral Decision Making 2, no. 3 (1989): 167-177. An organizational and cultural account is offered in an excellent field study by D. Vaughn, "The Challenger Launch Decision" (Chicago: University of Chicago Press, 1996).

7. R. Wohlstetter, "Pearl Harbor: Warning and Decisions" (Stanford, California: Stanford University Press, 1962); and G. Prange, "At Dawn We Slept" (New York: Penguin Books, 1981).

8. The biases mentioned here reflect multiple research streams that are too broad to cite fully. We suffice by listing some of the classic references, such as L. Festinger, "Conflict, Decision and Dissonance" (Stanford, California: Stanford University Press, 1964); I. Janis, "Groupthink: Psychological Studies of Policy Decisions and Fiascos," 2nd ed. (Boston: Houghton Mifflin, 1982); I.L. Janis and L. Mann, "Decision Making: A Psychological Analysis of Conflict, Choice and Commitment" (New York: Free Press, 1977); and H.H. Kelley and J.L. Michela, "Attribution Theory and Research," Annual Review of Psychology 31 (1980): 457-501.

9. The original and classic reference on groupthink is I. Janis, "Groupthink: Psychological Studies of Policy Decisions and Fiascos," 2nd ed. (Boston: Houghton Mifflin, 1982). For a critical review of groupthink as a psychological model, see W.W. Park, "A Review of Research on Groupthink," Journal of Behavioral Decision Making 3 (1990): 229-245.

10. The special challenges of organizational coordination and distortion are addressed in C.A. Heimer, "Social Structure, Psychology and the Estimation of Risk," Annual Review of Sociology 14 (1988): 491-519; E. Hutchins and T. Klausen, "Distributed Cognition in an Airline Cockpit," in "Cognition and Communication at Work," eds. D. Middleton and Y. Engstrom (Cambridge, U.K.: Cambridge University Press, 1996); and K.E. Weick and K.H. Roberts, "Collective Mind in Organizations: Heedful Interrelating on Flight Decks," Administrative Science Quarterly 38 (1993): 357-381.

11. "A Vital Job Goes Begging," New York Times, Feb. 12, 2005, Sec. A, p. 30.

12. Some classic sociological studies on organizational sense making include C. Perrow, "Normal Accidents: Living with High-Risk Technologies" (Princeton, New Jersey: Princeton University Press, 1999); and M. Douglas, "How Institutions Think," (Syracuse, New York: Syracuse University Press, 1986). See also L.B. Clarke and J.F. Short Jr., "Social Organization and Risk: Some Current Controversies," Annual Review of Sociology 19 (1993): 375-99; and L.B. Clarke, "Mission Improbable: Using Fantasy Documents to Tame Disaster" (Chicago: University of Chicago Press, 2001).

13. How organizations can maintain high reliability of performance in complex environments is addressed in E. Roth, J. Multer and T. Raslear, "Shared Situation Awareness As a Contributor to High Reliability Performance in Railroad Operations," Organization Studies 27, no. 7 (2006): 967-987; see also K.H. Roberts, "Some Characteristics of One Type of High Reliability Organization," Organization Science 1, no. 2 (1990): 160-176.

14. K.H. Roberts, "Managing High Reliability Organizations," California Management Review 32 (1990): 101-113; G.A. Bigley and K.H. Roberts, "The Incident Command System: High-Reliability Organizing for Complex and Volatile Task Environments," Academy of Management Journal 44, no. 6 (2001): 1281-1299; E. Hutchins and T. Klausen, "Distributed Cognition in an Airline Cockpit," in "Cognition and Communication at Work," eds. D. Middleton and Y. Engstrom (Cambridge, U.K.: Cambridge University Press, 1996); and K.E. Weick and K.H. Roberts, "Collective Mind in Organizations: Heedful Interrelating on Flight Decks," Administrative Science Quarterly 38 (1993): 357-381.

15. F.K. Boersma, "The Organization of Industrial Research as a Network Activity: Agricultural Research at Philips in the 1930s," Business History Review 78, no. 2 (2004): 255-72; F.K. Boersma, "Structural Ways to Embed a Research Laboratory Into the Company: A Comparison Between Philips and General Electric 1900–1940," History and Technology 19, no. 2 (2003): 109-126.

16. M.W. Dupree, book review of L. Galambos and J.E. Sewell, "Networks of Innovation: Vaccine Development at Merck, Sharp & Dohme, and Mulford, 1895-1995," Business History, Oct. 1, 1997.

17. A classic philosophical treatment of different approaches to gathering and interpreting information is C.W. Churchman's book "The Design of Inquiring Systems" (New York: Basic Books, 1971).

18. Sir Kevin Tebbit, interview with authors; also, see P. Bose, "Alexander the Great's Art of Strategy" (New York: Gotham Books, Penguin Group [USA] Inc., 2003).

19. From a brief discussion of the book in Wired, www.wired.com/wired/archive/12.06/view_pr.html.

20. For more detail on the case, see P.J.H. Schoemaker, "Profiting from Uncertainty" (New York: Free Press, 2002).

21. Royal Dutch Shell used scenario planning as a learning process to help reveal the implicit mental models in its organization. This form of institutional learning can be seen as a way for management teams to "change their shared models of their company, their markets and their competitors." A.P. de Geus, "Planning as Learning," Harvard Business Review 66 (March-April 1988): 70-74.

22. This was the original title of an internal Shell paper by Pierre Wack, the main founder of Shell's approach to scenario planning. The paper was later revised and published as two articles: P. Wack, "Scenarios: Uncharted Waters Ahead," Harvard Business Review 63, no. 5 (September-October 1985): 73-89; and P. Wack, "Scenarios: Shooting the Rapids," Harvard Business Review 63, no. 6 (November-December 1985): 139-150.

23. L. Bossidy and R. Charan, "Confronting Reality," Fortune, Oct.18, 2004, 225-229, excerpted from "Confronting Reality: Doing What Matters to Get Things Right" (New York: Crown Business, 2004).

24. K.A. Jehn, "A Multimethod Examination of the Benefits and Detriments of Intragroup Conflict," Administrative Science Quarterly 40, no. 2 (June 1995): 256-282. For an excellent discussion of management conflict and performance, see K.M. Eisenhardt, J.L. Kahwajy and L.J. Bourgeois III, "Conflict and Strategic Choice: How Top Management Teams Disagree," California Management Review 39, no. 2 (winter 1997): 42-62.

25. G. Morgenson, "How the Thundering Herd Faltered and Fell," New York Times, Sunday, Nov. 9, 2008.

26. G. Klein, "Sources of Power" (Cambridge, Massachusetts: MIT Press, 1998); also see R.M. Hogarth, "Educating Intuition" (Chicago: University of Chicago Press, 2001).

27. V. Barabba, "Surviving Transformation: Lessons from GM's Surprising Turnaround" (New York: Oxford University Press, 2004).

28. These unmet needs were identified in a study by Wirthlin Worldwide Inc. through two measures — the importance consumers placed on key factors that influenced their buying decisions and their current level of satisfaction with these factors.

29. This example is more fully discussed in P.J.H. Schoemaker and M.V. Mavaddat, "Scenario Planning for Disruptive Technologies," chap. 10 in eds. G. Day and P.J.H. Schoemaker, "Wharton on Managing Emerging Technologies" (New York: Wiley, 2000).

30. See M. Neugarten, "Seeing and Noticing: An Optical Perspective on Competitive Intelligence," Journal of Competitive Intelligence and Management 1, no. 1 (spring 2003): 93-104.

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