A reprint from

American Scientist

the magazine of Sigma Xi, The Scientific Research Society

To Signal Is Human

Real-time data mining unmasks the power of imitation, kith and charisma in our face-to-face social networks

Alex (Sandy) Pentland

Decades of research in social psychology have captured the surprising ability of people to "read" one another. In contexts as different as evaluating classroom teachers, selecting job applicants or foretelling jury decisions, accurate human judgments can be made on the basis of extremely thin slices of observational data. Across a wide range of studies, psychologists find that research subjects on average accurately predict outcomes in such pursuits 70 percent of the time. That success rate holds when predicting end results occurring days, weeks or even months later.

How is this possible? My theory is that our ability to read each other starts with what are known in biology as *honest signals*. Evolutionary models predict that social species are likely to develop honest signals, a reliable communication system that serves to coordinate behavior between individuals. Typically the signals include gestures, expressions and calls. Not only are they generally trustworthy cues, honest signals

Alex (Sandy) Pentland is the Toshiba Professor of Media, Arts and Sciences at Massachusetts Institute of Technology. He is a pioneer in computational social science, organizational engineering and mobile information systems. Pentland directs the Human Dynamics Laboratory and the Media Lab Entrepreneurship Program, which helps develop international applications for new technologies. Among the most cited computer scientists in the world, Pentland has cofounded more than a dozen companies. In 1997, Newsweek *named him one of the 100 Americans likely to shape the 21st century. His most recent book,* Honest Signals: How They Shape Our World, *was published in 2008 by The MIT Press. Address: Room E15-387, The MIT Media Lab, 20 Ames St., Cambridge, MA 02139 Email: pentland@mit.edu*

are also unusual because they trigger changes in people receiving the signals, changes that are advantageous to the people who send them.

It's likely that our human ancestors used such signals to coordinate their actions long before sophisticated human language evolved. A relative newcomer in hominid evolution, language was likely layered upon older primate signaling mechanisms that used social network strategies to find resources, make decisions and coordinate group action. By better understanding their influence today, we can shed light on the structure and function of modern social networks. For instance, honest signals can increase the energy level within a hunting team or, for that matter, a creative team through contagious excitement. They can create a more cohesive family group by increasing empathy and trust through mimicry signaling.

When we watch a conversation between two people and carefully measure the timing, energy and variability of the interaction, we find several examples of honest signals. My research group concentrates on four components of this human signaling. *Mimicry* is the reflexive copying of one person by another during a conversation, resulting in an unconscious back-and-forth trading of smiles, interjections and head nodding. *Activity* indicates interest and excitement, familiar to us from the connection between excitement and activity level in children. *Influence* of one person over another can be measured by the extent to which one person causes the other person's pattern of speaking to match theirs. And *consistency*, or fluidity, of speech and movement is perceived by others as a marker of expertise.

To measure the impact of these ancient social signals, we developed some very modern tools in order to practice what we call *reality mining*. We collect data mostly with custom-designed electronic badges and sometimes with "smart" phones and other electronic devices. The instruments uncover and quantify the role that social signaling mechanisms play in everyday decision-making. By examining the back and forth of signaling behavior in pairs and small groups—paying no attention to words or the identity of individuals—we can accurately predict outcomes of speed-dating encounters, job interviews, even salary negotiation outcomes. In a wide variety of situations ranging from business management to first dates to the effects of political opinion, we find that roughly 40 percent of variation in outcomes can be attributed to signaling-based models of social information processing. That is equivalent to some estimates of the influence of genetic makeup on individual behavior and is far too large, we believe, to ignore.

Influential Communication

Honest signals influence critical activities including negotiation, group decision making and group management. In fact, they are accurate predictors of human behavior. For example, if one member of a group is happy and bubbly, others will tend to become more positive and excited, an effect known as mood contagion. Moreover, this signaling-induced effect on mood serves to lower perceptions of risk within groups and to increase bonding. Similarly, people tend to mimic each other automatically and unconsciously. Despite being unconscious, this mimicking behavior

Figure 1. What President Lyndon Johnson was saying to U.S. Senator Richard Russell, a Georgia Democrat, no doubt mattered during what appeared to be a tense White House meeting in 1963. But non-verbal aspects of their exchange—so-called social signals—were likely important too. Observe the way each man holds his arms, mirroring the other. The author and his collaborators use electronic devices to capture the influence of such signaling between individuals and within groups. Their reality-mining research is contributing to a growing body of evidence finding that signaling plays significant roles in everyday persuasion and decision-making. (Photograph by Yoichi Okamoto, courtesy of the Lyndon Baines Johnson Library and Museum.)

has an important effect on participants: It increases how much they empathize with and trust each other. Not surprisingly, negotiations with lots of mimicry tend to be more successful, no matter which party starts copying the other's gestures first.

Each of these signals likely has roots in the biology of our nervous system. Mimicry is believed to be related to cortical mirror neurons, a distributed brain structure that seems to be unique to primates and is especially prominent in humans. Mirror neurons react to other people's actions and provide a direct feedback channel between people. Newborns, for instance, mimic their parents' facial movements despite their general lack of coordination. Simi-

larly, our activity level is related to the state of our autonomic nervous system, an extremely old neural structure. Whenever we need to react more vigorously—say in fight-or-flight situations or when sexually aroused—this system increases our activity level. On the other hand, we tend to be listless and less reactive when our autonomic nervous system is blunted, as during clinical depression. The relationship between autonomic nervous system function and activity level is tight enough that we have used it to accurately estimate the severity of depression.

The Habitual and Attentive Mind
How do social signals interact with language? Evolution rarely discards

successful working parts. It generally either builds additional structures while retaining the old capabilities or subsumes old structures as elements of the new. When our language capabilities began to evolve, our existing signaling mechanisms most likely were incorporated into the new design. The question is then: How has modern human society been shaped by our ancient signaling mechanisms, and to what extent do these mechanisms still govern our lives?

A partial answer to this question can be found in the work of psychologist Daniel Kahneman and artificial intelligence pioneer Herb Simon, both Nobel Prize winners. Each embraced a model of a human mind with two parts: a
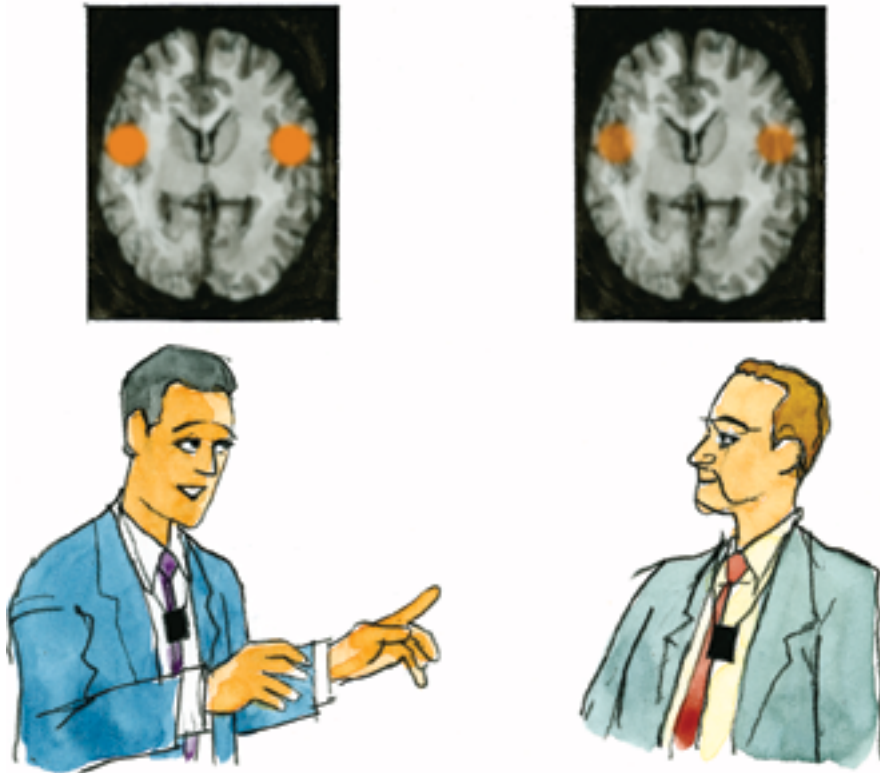
Figure 2. Specialized brain cells likely enable human social signaling. Mirror neurons, believed to reside in the inferior frontal gyrus and in the inferior parietal lobule, may be involved in our tendency to mimic one another. Marco Iacoboni at the University of California at Los Angeles and other neuroscientists argue that mirror neurons allow people to internally experience the observed actions and feelings of others, which facilitates empathy.

habitual, automatic and largely unconscious, mind, along with an *attentive*, reasoning and largely conscious mind. It is likely that the habitual mind represents an older system and contributes mental capabilities similar to those held by early humans: being fast, good at complex trade-offs and associations, but not very adept at what we think of as abstract reasoning. Correspondingly, the communication abilities of this early human mind would likely be limited to signaling and simple signs. Although the habitual mind is quite capable of learning new behaviors through experience or mimicry, such learning likely is limited to associations among perceptual features.

The ability to go beyond association-based learning may be the key contribution that the attentive mind makes to the fitness of our species. There are inherent limitations to learning using associational mechanisms and Kahneman has speculated that these limitations probably spurred the evolution of the attentive mind. In addition, the linguistic capabilities of the attentive mind allow much faster spreading of new behaviors among a population.

Of Kith and Kin

One of the surprising conclusions from our studies of social signaling in everyday situations is that the attitudes and actions of peers, rather than logic or argument, often dominate people's beliefs and actions. It seems that our forebears understood this intuitively and more than a 1,000 years ago had a name for it: *kith*. "Kith and kin" is an archaic phrase that still rings familiar, but most of us don't know the meaning of kith. The word derives from old English and old German words for knowledge, and it means a more or less cohesive group with common beliefs and customs. These are also the roots for *couth*, which means possessing a high degree of sophistication, as well as its more familiar counterpart, uncouth. Thus, your *kith* is the circle of peers (not just friends) from whom you learn sophisticated habits of action.
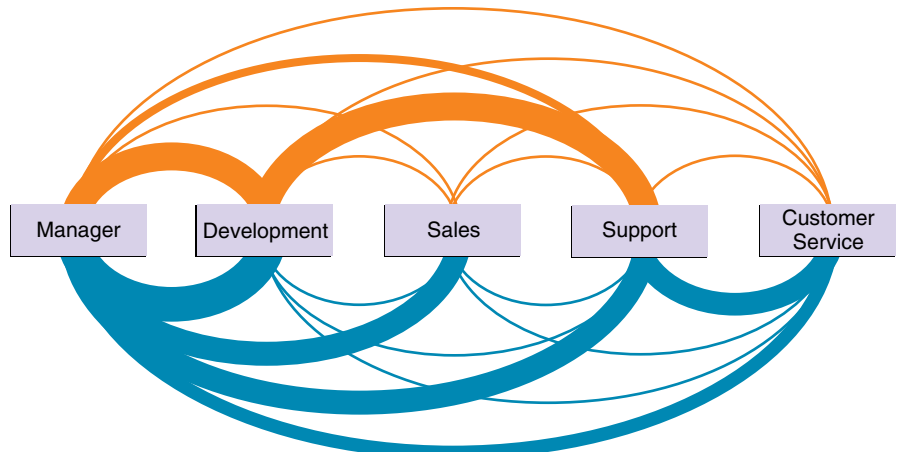

Figure 3. Real-time observation of face-to-face interactions requires the right tools. Custom-designed electronic badges, (*top left*), measure a person's tone of voice, body posture and gestures, along with proximity and posture relative to other people. Smart phones also can track who is near whom. The resulting data, depicted in orange above, can be used, along with e-mail communication, depicted in blue, to map exchanges within an organization. This example comes from observations in a German bank where employees were developing an advertising campaign. It exposed limited face-to-face contact by many on the team with customer service staff, who likely had useful insights to contribute to the campaign. (Photographs courtesy of the author.)

It appears that the English had the right idea 1,000 years ago about how people learn. We are ruled by common sense, the habits our kithmates have in *common*. This social learning works by modifying us through social pressure (usually mediated by social signaling), instead of through critical reasoning. The use of kithmates to form common-sense habits is another clue to how early humans may have leveraged the social signaling mechanisms to make better decisions.

Imitative learning from kithmates may be why allowing more time around the water cooler or coffee pot may be the simplest way to increase workers' productivity. Why? In our studies of more than a dozen organizations, we have found that cohesion among peer employees—kithmates—is one of the largest factors in both productivity and job satisfaction. In these instances, cohesion is defined as how connected kithmates are with each other. That is, do the people you talk to also talk to one another? How tightly woven and interconnected is your peer network?

In one study in Chicago, we used electronic badges to monitor the social signaling and conversational patterns of information technology specialists. The badges were fitted with infrared sensors, Bluetooth location measurement and accelerometers to measure body movements, and recorders that captured the pitch and pace of voices. We found that peer-group cohesion was a central predictor of productivity. In fact, workers whose group cohesion was in the top third had more than 10 percent higher productivity when compared to the mean. This result underscores the extent to which we are social animals and that our connection with our peers at a local level is vitally important. With increased cohesion comes an increase in sharing things such as tacit knowledge, attitudes, work habits and social support. In other words, much of the important information about how to be successful and productive at a job is likely to be found in the break room.

Tapping Collective Intelligence

But is it good for people to be confined by *common* sense—that is, the beliefs of those around them? To answer that, it is important to understand how social-signaling mechanisms help people decide when to be guided by kithmates and when to follow a separate path.
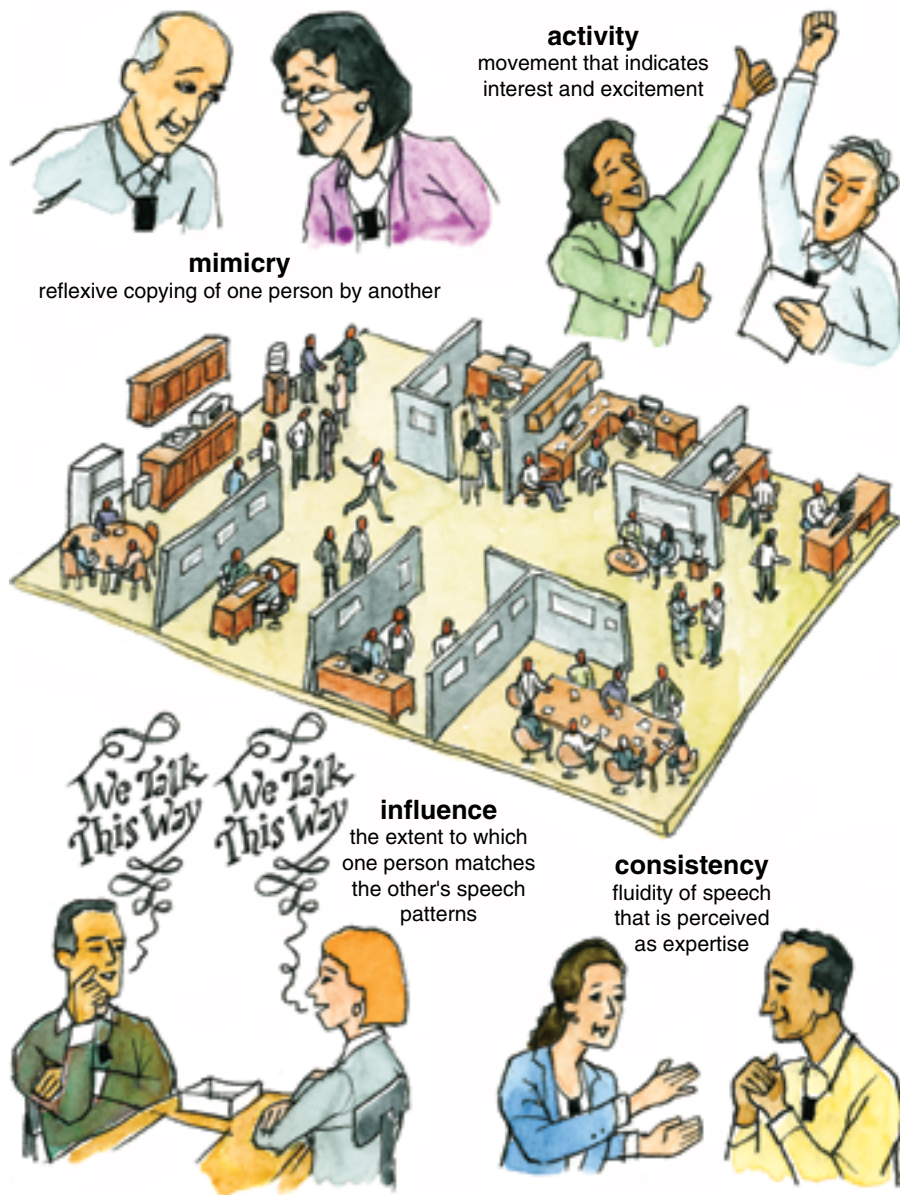

Figure 4. Until very recently, it was impossible to record social signaling in natural settings over any length of time. But advances in electronics, battery size and computational analysis make it possible to record signaling in both small and large groups. The author and his collaborators frequently focus on signaling that predicts cooperation among individuals, including qualities such as mimicry, increased activity levels, adoptions of another's speech pattern and consistency, or fluency, in speech. Using data about such signals, social scientists can now predict outcomes in interactions with surprising success.

From a theoretical point of view, perhaps the simplest, most effective way to integrate individual preferences into useful common sense is through an *idea market*. Idea markets resemble voting, but instead of building on a single vote per person, we allow people to express their expectations of the returns associated with multiple courses of action. For instance, how much food will we find if we go over the hill? How much will we find if we go across the river? And so forth for each alternative. One can think of these expectations as bets and use standard probability theory to weight the bets in proportion to their expected payoff. In this way we can select the action that maximizes the expected return and minimizes the risk.

People naturally create idea markets using social signaling. Everyone bets on each suggested action by signaling a level of interest—say with the energy in their voices or their movements. Then group members "add up" the signaling to pick the option with the most positive signaling. This method of decision-making doesn't require language. In

order to pick the winning course of action, each participant must only signal to the rest of the group how interested they are in each alternative and then be able to read the group's combined signaling. Animal-behavior research supports the idea that this is what both social bees and apes do when deciding about group movements. It also is similar to the initial-reaction signaling seen in business meetings. Those "ums," "ahs" and "hmms" so common in conference rooms, along with the animated or slack body postures, suggest how our modern decision-making processes preserve and leverage these ancient mechanisms.

Still, the challenges individuals face change dramatically over time. As a consequence, social signaling mechanisms must allow us to quickly select the right kithmates to help solve the newest problems. This really is a question of identity: The character of the problem determines who will be the best kithmates for learning new, effective actions. This poses a problem for decision making by social signaling, however, because when people are faced with new, important decisions, they need to quickly form peer groups that are relevant to the problem. Thus, we need to determine whether or not people dynamically form problem-defined kith groupings in modern daily life.

To test this idea, we monitored the social signaling and patterns of interaction for 81 residents in an MIT dormitory during the 2008 presidential elections, giving them smart phones that could track who spoke face-to-face with whom. What we found is that when politics became especially prominent, as during a presidential debate, the students shifted their groupings and began to selectively spend time with others who shared the same ideological position, excluding those holding opposing opinions. This was not true of communication channels with no face-to-face contact, such as phone calls; those remained unchanged, perhaps because they are less effective at conveying social signals.

Further, the extent to which students formed a cohesive kith with people possessing similar opinions predicted their level of interest in the presidential race, their liberal-conservative balance and even their eventual voting behavior. For first-year students, the magnitude of this effect was similar to the effect detected in experiments

evaluating political advertising and media exposure. The finding reinforces the view that when people are faced with important decisions, they tend to form cohesive, reinforcing peer groups, allowing social signaling to cement shared ideas and attitudes.

Whence Creativity?

We have seen that these signals have a major effect on person-to-person interactions and on group behavior, but do they influence even our most sophisticated abilities? As it turns out, the humble honeybee has much to tell us about the flow of information in social species. It is common knowledge that worker bees search for good food sources and then return to the hive and use waggle-dance signaling to communicate the distance and direction of the food source. Less well known, though, is that bees use this same mechanism as the basis for an elegant approach to group decision-making.

One of the most important group decisions made by a bee colony is where to locate a nest. Bees seem to use a kind of idea market to guide their discovery: The colony sends out a small number of scouts to survey the environment. Returning scouts who have found promising sites signal their dis-

covery with an intense, active dance. As a result of this social signaling, more scouts are recruited to the better sites. This cycle of exploration and social signaling continues until, eventually, so many scouts are signaling in favor of the best site that a tipping point is reached and the hive moves *en masse*. (See, for example, "Group Decision Making in Honey Bee Swarms," *American Scientist*, May–June 2006.)

The bees' decision-making process highlights information integration as well as information discovery. These two processes are crucial to every organization but each has different requirements. The solution suggested by the bees is to alternate between star-shaped, one-to-many networks that are best for discovery and a richly connected, many-to-many network that is best for integration. Networks—whether apian or human—that vary their communication structure as needed are able to shape information flow to optimize both discovery and integration.

Our studies at MIT have shown that this same sort of oscillation between discovery and integration seems to be characteristic of creative teams of people. In one study we tracked employees in the marketing division of a German bank, capturing informa-

Figure 5. Social organisms can use different social signals and different patterns of communication for different functions. For instance, honeybees will perform a waggle dance to spread news about a promising new food source for their community. This is an example of a star-shaped, one-to-many pattern of communication. The dance can also assist with group decision making. Intense dancing recruits more scouts to examine a site until many scouts end up signaling to each other about one location. When enough scouts signal the same location, a consensus is reached and the hive moves *en masse*. This is an example of a richly connected, many-to-many pattern of communication.

Figure 6. Charisma is one quality that helps individuals bring new ideas to a group. Many influential people have displayed it, including Mahatma Gandhi *(right)* the champion of nonviolence and leader of India's independence movement. While in England in 1931, Gandhi visited workers in the mill town of Darwen in Lancashire, where India's boycott of cotton goods was taking a toll on local industry. Still, people there responded warmly to him.

Underwood & Underwood/CORBIS

tion about their social signaling during each encounter. Analysis of the data showed that teams charged with creating new marketing campaigns oscillated between two communication patterns. In one they placed themselves in the middle of multiple streams of communication, a centralized communication pattern that is associated with discovery. In the second, they engaged in a densely interconnected pattern of communication where most conversations were with other team members. In contrast, members of production groups showed little oscillation, speaking mostly to other team members. A second study demonstrated that creative teams not only had more variation in the shape of their social communication networks, but also that the range of variation in network shape correlated with how creatively productive the groups judged themselves to be. Oscillation in the shape of these networks, in other words, can predict creative productivity, at least as defined by the people in the networks.

Why might this pattern promote greater creative output? One way to interpret these findings is that this pattern of oscillation brings new information to a group for integration into people's habitual minds. Because the habitual mind uses association rather than logic, it can more easily make intuitive leaps and find new, creative analogies. It can take the experience of a new situation, let it "soak in" for a while and then produce an array of analogous actions.

There is considerable literature showing that unconscious cognition is more effective than conscious cognition for complex problem solving. The habitual mind seems to work best when the more logical attentive mind isn't interfering, such as during sleep or when we are "turning it over in the back of our mind." In contrast, the attentive mind provides insights into our actions, helping us detect problems and work though new plans of action.
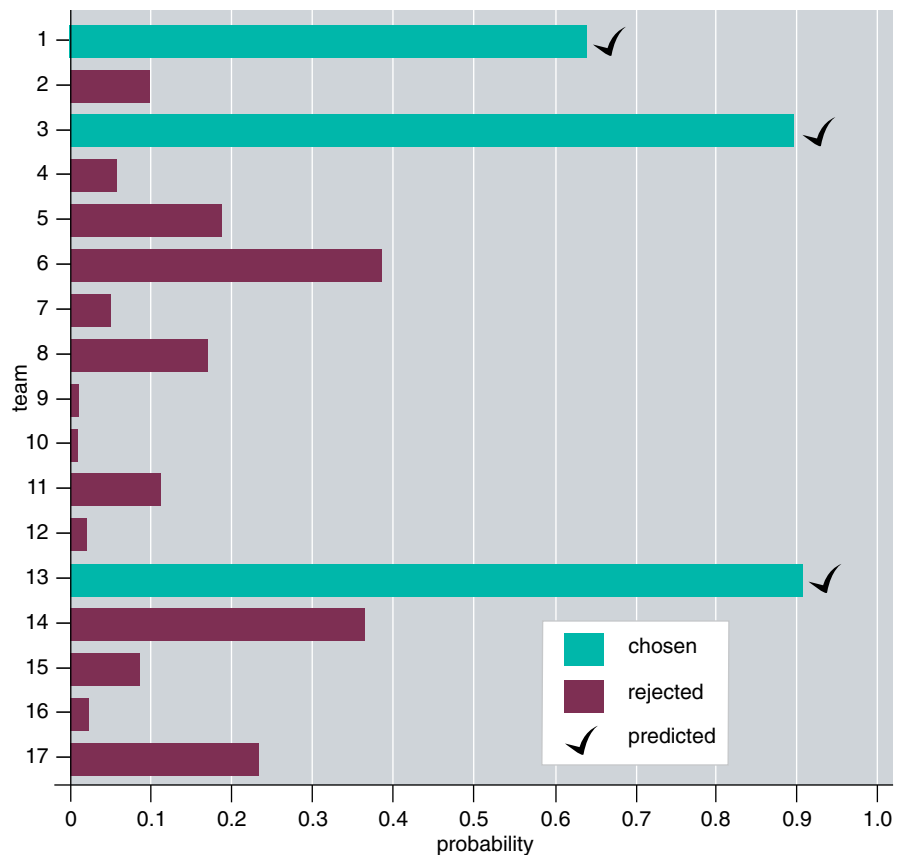

Figure 7. By measuring the expression of qualities associated with charisma, the author's research team was able to predict which business executives would convince a group to support their business plans during an exercise hosted at MIT. Among the qualities measured were active patterns of socialization on the part of speakers, meaning they interacted with many people; high influence on the patterns of the conversations they participated in; and high activity levels, which can convey enthusiasm.

Figure 8. At an MIT Media Lab event for its corporate sponsors in Tokyo in 2008, graduate student Ben Waber explains a social-network visualization produced by tracking people at the event who were wearing sociometric badges. Such patterns of interaction now can be observed in real time in large and small groups. The technology offers promise but also introduces ethical issues that must be addressed regarding ownership and fair use of the resulting data. (Photograph courtesy of the author.)

The Power of Charisma

Although using social-signaling mechanisms for making decisions appears to be good for combining action alternatives and interests, it is likely not to be good for learning new behaviors. This is because the idea market combination mechanism tends to select only consensus views and is unfriendly to new or unusual alternatives. It leads to a very stable, conservative social group. This resistance to change raises the important question of how social-signaling mechanisms might have facilitated learning of new action habits from examples outside the community.

One possible mechanism is the phenomenon of charisma. Although no one has fully defined charisma, research subjects reliably agree on its characteristics. In particular, most report that charisma is much more than just word choice or argument. We can understand at least a pedestrian sort of charisma if we define it by its operational characteristics: an unusual ability to convince others to try out a new behavior. Under this definition, people who are good at pitching business plans, building high-performance teams and succeeding at similar activities demonstrate the quality. Importantly, many of these charisma qualities seem to involve social signal-ing. In our studies, we have observed that there is a certain style of social interaction—one that we can identify quantitatively and automatically by computer processing of voice and gesture—that is highly predictive of success at influencing others' behavior in a variety of situations.

To illustrate, consider our study on business-plan pitches. In that study, a group of rising-star business executives gathered at MIT for an important task. Each executive presented a business plan to the group, and the group then chose what they concluded were the best ideas. The executives wore our badges, which captured their styles of social signaling. By analyzing that signaling, we were able to predict with a high degree of accuracy which business plans the executives would choose. Our executives, it seems, were busy measuring the social content of the presentations, quite apart from the spoken, informational part.

To understand why this makes sense, consider the situation in more detail. Imagine you are listening to a business plan pitch on an unfamiliar topic. Although you don't know much about the subject, the speaker's presentation is fluid and practiced. Also, the speaker is noticeably energetic and clearly excited. Your habit-ual mind says to itself, ``Well, I may not know much about this, but she is clearly expert and she is excited … so I guess it must be a good plan.'' This successful presentation style is charismatic by our definition, because is it effective at convincing people to consider new behaviors.

Similarly, another recent study from our research group focused on executives attending an intensive one-week executive education class at MIT where the final project, again, was pitching a business plan. This time we used our electronic badges to observe the executives during a mixer on the first evening of the course. We found that their social styles at the mixer were predictive of how well their teams' business plans would be perceived at the end of the course. The most successful style is what we call the "charismatic connector." These people circulated in the crowd, practiced intense listening, had fluid speaking styles and tended to drive conversations with questions.

The more charismatic connectors a given team had among its members, the better the team was judged during the business-plan pitch. The reason seemed to be that the members worked together better. In teams whose social style was dominated by these charismatic connectors, team discussions were characterized by more even-handed turn-taking, high levels of engagement and higher productivity. These two characteristics—charisma and connector—usually go together. We have found that the people who have the most consistent and influential style of speaking are also the people who are the greatest connectors. People whose social networks cross many different groups are exactly those people who display a charismatic style of interaction.

Under the Signaling Influence

Our research suggests that people's behavior is much more a function of their social network than generally imagined. Humans truly are social animals, and individuals are best likened to musicians in a jazz quartet, forming a web of unconscious reactions tuned to exactly complement the others in the group. These various studies from my research group all serve to demonstrate that this immersion of self in the surrounding social network is the typical human condition, rather than an isolated example found in ex-

ceptional circumstances. Our ancient reflexes for unconscious social coordination fuse us together into problem-oriented peer groups—our kith. And those groups strongly influence our actions every day.

What practical conclusions can we draw from this? These results tell us that individuals should consciously work toward having a cohesive, engaged set of kithmates, helping them adopt more effective habits of action. There is solid evidence that people involved with such kithmates are not just more productive and creative. They are also happier, more resilient and more satisfied. And how can one go about collecting this set of valuable mates? The charismatic connector style of signaling we have uncovered may be the single most important factor in promoting the success of group activities, by creating a contagious positive mood, increasing trust and encouraging more even, socially aware participation. It may be time to begin training people to become more like these connectors.

Reality mining offers promising insights such as these because its large data sets reveal social patterns that once were invisible, showing us pictures of hundreds, even thousands, of people working together. Of course this method raises ethical issues that must be addressed. Such data also pose a potential threat to individual privacy. Because of that, it is important that individuals rather than corporations own the data used for reality mining. To my mind, that would place control of the data's use with the observed individuals, where it belongs. And it would also allow the individual owners to derive personal value from this important knowledge source as we strive to understand how we can better work together.

Bibliography

Ambady, N., and R. Rosenthal. 1992. Thin slices of expressive behavior as predictors of interpersonal consequences: A meta-analysis. *Psychological Bulletin* 111:256–274.

Barsade, S. 2002. The ripple effect: Emotional contagion and its influence on group behavior. *Administrative Science Quarterly* 47:644–675.

Buchanan, M. 2009. Secret signals: Does a primitive, non-linguistic type of communication drive people's interactions? *Nature* 457:528–530.

Buchanan, M. 2007. The science of subtle signals. *strategy+business* 48:1–10.

Couzin, I. D. 2009. Collective cognition in animal groups. *Trends in Cognitive Sciences* 13:36–43.

Iacoboni, M., and J. C. Mazziotta. 2007. Mirror neuron system: basic findings and clinical applications. *Annals of Neurology* 62:213–218.

Pentland, A., with T. Heibeck. 2008. *Honest Signals: How They Shape Our World.* Cambridge, Mass.: MIT Press.

Zahavi, A., and A. Zahavi. 1997. *The Handicap Principle: A Missing Piece of Darwin's Puzzle.* Oxford: Oxford University Press.