Counterpoint Global Insights

Pattern Recognition

Opportunities and Limits

Introduction

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In 1990, I was junior equity research analyst supporting a senior analyst who covered stocks in the food, beverage, and tobacco industries. After the market closed on June 7, ConAgra Inc (now Conagra Brands) announced it was acquiring the food operations of Beatrice Company. These included popular products such as Peter Pan peanut butter and Orville Redenbacher popcorn that gave Conagra access to a section of the supermarket where it had no presence.[1]

Kohlberg Kravis Roberts & Co. (now KKR & Co.) had taken Beatrice private for more than $8 billion in 1986, then the largest leveraged buyout in history. KKR quickly sold most of the conglomerate's divisions, including Avis Car Rental, Coca-Cola Bottling, and Tropicana. There were a lot of lookers, but no takers, for the food business at the price KKR sought.[2]

The assets that remained at Beatrice were desirable, but the accounting for the purchase made it "something of a white elephant."[3] Under purchase accounting, the buyer would have to assume $2.4 billion in "unallocated purchase cost," effectively goodwill, that it would have to amortize over 40 years. This meant an accounting charge against earnings of nearly $60 million per year that most companies preferred to avoid.[4]

Beatrice sold for $1.34 billion and the assumption of about $1 billion in debt, less than one-half of what KKR had hoped for originally. But Conagra structured the payment to be tax efficient for the sellers, and the annualized return on the equity in the Beatrice LBO was reported to be as high as 50 percent.[5]

Conagra arranged for information packets about the deal to be delivered to Wall Street analysts after the close of the market (this was before the dawn of the commercial internet). The senior analyst handed me the packet as he headed out the door and asked me to do the analysis. He indicated he would update his thoughts on the stock at the morning call the next day.

The analysis did not take long. Beatrice appeared to be a good strategic fit for Conagra, and the cash flows showed that the deal created value for shareholders despite the potential impact of goodwill amortization. Indeed, Conagra's management correctly understood goodwill amortization as an accounting rather than an economic cost.[6]

The senior analyst came in the next morning and said he was downgrading the stock based on his experience. He was a Wall Street veteran and recognized a pattern. There were two things that made him pessimistic about the stock's potential reaction to the news: the fact it was an acquisition and the possible drag on earnings from amortization. Most merger and acquisition (M&A) deals fail to create value for the acquiring company, and a hit to earnings is perceived to be bad.

Conagra's stock rose about 4 percent that day and the S&P 500 fell roughly 1 percent. The S&P 500 is an index that tracks the stocks of 500 of the largest companies listed in the U.S.

This report is about the powers and perils of pattern recognition. Investors and investment organizations regularly cite pattern recognition as the basis for action.[7] While it can be extremely powerful and useful when applied appropriately, it can also be highly misleading and furnish fuel for overconfidence when used inappropriately.

We will define pattern recognition, discuss when it tends to work well, review why it may be misleading, and offer some ways to help improve it.

Definition

The Merriam-Webster dictionary defines "pattern" as "a reliable sample of traits, acts, tendencies, or other observable characteristics of a person, group, or institution" and "recognize" as "to acknowledge or take notice of in some definite way."[8] So pattern recognition is an awareness that what is happening now has happened in the past and offers a predictable sense of what's going to happen in the future. Investors with experience commonly sense they recognize patterns because they have a mental database of events and outcomes.

Pattern recognition works at the intersection of intuition and expertise.[9] Intuition is the immediate sense of understanding something without conscious thought. In fact, Herbert Simon, a polymath who made major contributions to computer science, economics, and cognitive psychology, stated flatly that, "Intuition is nothing more and nothing less than recognition."[10]

Expertise can be described as "consistently superior performance on a specified set of representative tasks for a domain."[11] Becoming an expert generally requires devoting a large amount of time to deliberate practice in an environment where there is unambiguous feedback. Experts perceive patterns in their domains, solve problems qualitatively, and answer problems much faster and represent them at a deeper level when compared to novices.[12]

The words experience and expertise share the same Latin root, but distinguishing between them is crucial. Gregory Northcraft, a social psychologist and professor emeritus at the University of Illinois, suggests the following difference: "There are a lot of areas where people who have experience think they're experts, but the difference is that experts have predictive models, and people who have experience have models that aren't necessarily predictive."[13]

Experience leads to expertise only when there is learning guided by clear and timely feedback. In instances when there is wiggle room in assessing the quality of decisions, those with experience may talk a better game than those without experience but offer judgments that are in the aggregate no better than average.[14] Expertise applies under a relatively narrow set of conditions.

Work on expert political judgment by Phil Tetlock, a professor of psychology at the University of Pennsylvania, makes this point emphatically.[15] Tetlock had 284 experts make a total of 28,000 predictions associated with political and economic outcomes from 1984 to 2003. A majority of Tetlock's participants had doctorate degrees, and on average they had more than a dozen years of work experience. He defined an expert as someone who makes a living by providing advice regarding political or economic trends.

The forecasts by the experts were little better than chance and usually worse than those produced by simple extrapolation algorithms. Further, he found that predictions by the participants were commonly based on "case-specific hunches about causality that make some scenarios more 'imaginable' than others."[16] They had experience but lacked predictive models that were accurate.

Tetlock's description of how the experts he studied came up with forecasts appears very similar to what investors do. For example, a survey of more than 250 holders of the Chartered Financial Analyst designation, more than half of whom had 15 years or more of experience, revealed that 92 percent agreed with the statement, "The ability to construct a coherent and complete 'story' with the facts of a situation is the most important task when making a decision or recommendation."[17]

Heuristics and biases are a central area of research in cognitive psychology. Heuristics are mental shortcuts, or rules of thumb, that people use to make judgments. In general, heuristics are useful because they are fast and often accurate. But heuristics can lead to biases, or departures from an ideal decision-making process.[18]

Tetlock's participants and the CFA charterholders both appear to use the representativeness heuristic. This is when a decision maker anticipates what will happen next based on an event, or events, that appear representational of the situation under consideration. This allows a forecaster to craft a compelling story. This heuristic is a form of intuition that introduces bias when events are not as correlated as the decision maker perceives.

Research shows that both intuition and expertise work in some settings and fail in others.[19] Understanding where and why intuition and expertise are effective is essential for knowing when pattern recognition is effective.

When Does Pattern Recognition Work?

Gary Klein is a psychologist who is one of the leading advocates for the role of expert intuition in decision making.[20] Daniel Kahneman, a psychologist who won the Nobel Memorial Prize in Economic Sciences, has shown how decisions based on intuition commonly depart from normative economic theory, especially in realms of uncertainty and risk.[21] The two got together and worked on what Kahneman called his "most satisfying experience" in adversarial collaboration, defined as "a good-faith effort to conduct debates by carrying out joint research."[22]

They found that intuitive expertise and pattern recognition tend to work well in stable environments where cause and effect are clear and participants can receive timely and accurate feedback. The classic example is chess. Skilled chess players can rapidly see which side of the board has an advantage and often quickly identify optimal, or close to optimal, moves. Chess masters, roughly the top one percent of rated players, recognize telling

patterns on the board based on groups of pieces, called "chunks." A chunk is effectively a unit of information that allows an expert to absorb lots of accurate cues about the game.[23]

If stability and feedback are essential to successful pattern recognition, instability and unclear links between cause and effect show where pattern recognition fails. Robin Hogarth, a cognitive psychologist, distinguishes between "kind" and "wicked" environments. In kind environments, outcomes are indicative of the quality of the process and feedback is accurate and plentiful. In wicked environments, outcomes are a poor or misleading reflection of process because causal links are blurred.[24]

Expert agreement is one way to assess the validity of intuitive expertise.[25] In kind environments, experts tend to agree on cues and the appropriate decisions that follow. For example, chess masters are likely to identify similar moves as attractive.

In wicked environments, the views of experts often vary substantially. For instance, the one-year forecasts of the level of long-term interest rates by economists are not much different from random.[26] Predictions of stock market returns by strategists and executives also tend to be poor.[27]

James Shanteau, a professor of psychology, summarizes the conditions for good and poor expert performance (see exhibit 1). In reality, you can think of expert performance across a continuum, from excellent to close to random. Shanteau adds some other relevant considerations. One is access to decision support systems. For instance, weather forecasters make very accurate short-term forecasts and largely agree with one another because they use sophisticated models that predict atmospheric conditions. But strategists or economists with equal credentials will have varying views on the probability of a recession or the price of oil one year from now.

Exhibit 1: Characteristics for Good and Poor Expert Performance

Property characteristic	Good performance	Poor performance
Stimulus stability	Static	Dynamic
Type of decision	Physical system	Behavioral system
Experts agree on cues	Yes	No
Domain context	Predictable	Unpredictable
Errors in decision making	Tolerated	Not tolerated
Repetitive tasks	Yes	No
Outcome feedback	Available	Unavailable
Problem decomposition	Yes	No
Use of decision aids	Routine	Not routine

Source: James Shanteau, "Why Task Domains (Still) Matter for Understanding Expertise," Journal of Applied Research in Memory and Cognition*, Vol. 4, No. 3, September 2015, 169-175.*

Another consideration is whether experts agree with their prior judgments when presented with similar, or even identical, input over time. For example, wine judges commonly score the same wine differently over separate occasions.[28] This is consistent with what Kahneman calls "noise."[29] Noise occurs when people with the same job come up with different judgments about a specific task or when an individual comes up with different judgments with the same input at different times. Note that noise reflects errors that are all over the place. That is distinct from bias, where errors are wrong in the same way.[30]

The answer to whether pattern recognition is useful for investing is tricky. We can start by assuming that long-term stock market returns combine fundamental company performance (e.g., sales growth, profits, return on investment, payout ratio) and macroeconomic factors (e.g., interest rates, risk premia, economic growth,

inflation). But a complicating factor is that the stock market reflects expectations about these inputs. Changes in expectations play a large role in stock price performance, especially in the short to intermediate term.

Quantitative investors seek patterns, ideally supported by economic logic, to construct portfolios that aim to generate attractive returns after considering risk. A quantitative model is a decision support system. Quantitative investors seek factors that are associated with excess returns relative to a basic asset pricing model. For example, the stocks that are cheap on multiples of book value or cash flow (value factor) have historically generated higher returns than stocks that are expensive (growth factor).[31] Humans add value by building and updating the model.

Fundamental investors rely less on decision support systems and more on pattern recognition.[32] Many build portfolios by seeking to select attractive securities based on bottom-up analysis. Specific events, such as the acquisition described in the introduction, often trigger a sense of pattern recognition. Fundamental investors are more vulnerable to seeing patterns that are unreliable or do not exist than quantitative investors because they are less reliant on decision support systems. Indeed, in more uncertain environments people are less likely to use algorithms.[33]

We now look at why pattern recognition fails.

Why Does Pattern Recognition Fail?

Humans are natural pattern seekers, a quality that likely conferred evolutionary advantage. Patterns have been useful for much of the history of humankind because the environments were relatively stable and cause and effect were evident. Our modern world has created systems where cause and effect are obscure. As a result, well-intentioned human interventions in complex social or natural systems commonly produce unintended consequences. Pattern recognition often fails in complex and evolving environments.

Complex adaptive systems are an example of such an environment. "Complex" reflects lots of agents that interact. "Adaptive" means that agents learn and evolve to reflect changes in the environment. And "system" means that the whole that emerges has behaviors that cannot be readily explained by the agents alone. Ant colonies, cities, ecologies, economies, and stock markets are examples of complex adaptive systems.[34]

Properly identifying patterns within these systems is hard because cause and effect is not always clear. These systems also commonly exhibit non-linearity, where a small perturbation leads to a large outcome.

An open letter to Ben Bernanke, then chairman of the Federal Reserve, about the perils of quantitative easing is a good example of illusory links. Quantitative easing, a form of monetary policy, describes when a central bank purchases assets in the open market to lower interest rates and increase the supply of money. Written by prominent economists, strategists, and investors and shared in November 2010, the letter suggested quantitative easing risked "currency debasement and inflation."[35] Neither debasement nor inflation were issues in the years that followed. The pattern of quantitative easing leading to a lower dollar and inflation did not manifest.

One of the ways that non-linearity shows up in markets is through the loss of diversity. The economist Blake LeBaron is a leader in the field of agent-based modeling. These are models that create agents in silico, provide them with decision rules, and let them trade an asset among themselves. The asset has a fair value based on dividends. LeBaron tunes the model to generate asset price movements consistent with empirical reality, including clustered volatility and fat tails. The virtue of this approach is that he can measure the diversity of the decisions the agents make.

What he finds is that the asset price rises even as the diversity of decision rules declines because the similar trading strategies reinforce the price movement. But at some point the market becomes fragile. At that critical juncture, a small incremental loss of diversity leads to a sharp plunge in the asset price because the buyers are exhausted. The relationship between diversity loss and asset price change is non-linear. Diversity breakdowns fit a pattern but measuring diversity is inherently difficult.[36]

Pattern recognition can also fail because of how our minds love to think in analogies. Steps include selection, mapping, evaluation, and learning.[37] To understand a target topic we commonly start by selecting an analog, usually from memory. We map the target based on the source analog, seeking to make inferences. We evaluate these inferences to judge the similarities and differences between the target and the source. We then learn how the success or failure of the analog applies to the target.

Finding the correct analogy is valuable but rare. Pitfalls in the process are the result of breadth and depth. Breadth reflects that we simply have insufficient memory to recall and identify a proper analogy. Depth means the similarities we identify are often superficial and not based on causal factors. The analogy may not work but it creates what Phil Tetlock calls "imaginable scenarios." In studies, participants gain more accurate information when researchers prompt them to consider more than one analog.[38]

Because our minds are so good at making analogies, we run the risk of apophenia, defined as "the tendency to perceive a connection or meaningful pattern between unrelated or random things."[39] In the extreme, this can lead to conspiracy theories, superstitions, and false interpretations of randomness.

In fact, there is a module in the left hemisphere of our brain that seeks to create a narrative that links cause and effect. Neuroscientists call this "the interpreter."[40] We are wired to see connections where none exist. The strategy of "frequency matching," where the frequency of choices among alternatives matches the frequency of the reward, is one example. But before discussing how and why adult humans do this, we will learn a lesson from how pigeons decide.

Scientists placed White Carneaux pigeons, the breed that the behaviorist B. F. Skinner had used in his work on conditioning, into an "operant-conditioning chamber" that had two keys they could peck. The researchers set it up so that one of the keys had a higher chance of a food reward than the other. The pigeons figured out which key was better and hit it nearly every time. As a result, they got close to the optimal payoff. Kids under the age of four and rats come to the same strategy.[41]

Adult humans, on the other hand, tend to frequency match. After discovering the probabilities, humans go back and forth between the keys in an attempt to guess the next outcome. They seek a pattern. They select the higher payoff key at a rate that matches the frequency of the payoffs, but still go back and forth between the keys trying to anticipate the rewards. This strategy has a lower payoff than simply selecting the higher payoff key every time.[42]

Humans frequency match from the time they enter kindergarten on. Here is where the interpreter within the left hemisphere comes in. Neuroscientists studied split-brain patients to figure out where in the brain decisions happen. These are patients with severe epilepsy that doctors treat by surgically cutting the bundle of nerves between the brain's two hemispheres to relieve the symptoms of epilepsy.

The surgery allows scientists to create experiments to assess which parts of the brain deal with various tasks. Researchers worked with these unusual participants to figure out where the inclination to seek patterns resides.

The right hemisphere tends to be literal, so it is good at tasks such as facial recognition but bad at making inferences. The left hemisphere is where the circuitry for language largely sits, and it is also great at fabricating narratives to fit facts.

Researchers found that when presented with a version of the probability guessing experiment, the right hemisphere of split-brain patients maximized just as the pigeons, rats, and little kids did. But when shown the same experiment, the left hemisphere of the patients tried to match the frequency.[43] Your left hemisphere is inclined to see patterns where none exist.

Another reason that pattern recognition fails is that investors often extrapolate. Jason Zweig, a financial journalist, cites an experiment where researchers showed participants a random sequence of squares and circles while monitoring their brain activity with functional magnetic resonance imaging (fMRI). After seeing two squares or circles in a row, the brain of the participants anticipated another of the same symbol.[44]

The neuroscientists who did this work conclude, "The human cognitive system identifies patterns in sequences of events, regardless of whether a pattern truly exists."[45] In this case, the pattern is "what just happened is going to continue happening."

Ben Graham, the father of security analysis, shared a cautionary case study about a company called AAA Enterprises. The high-flying stock was first issued to the public in 1969 at $13 per share and immediately shot up to $28 despite flimsy fundamentals.[46] But the stock was grounded shortly thereafter, reaching $0.50 per share in early 1971, as the firm filed for bankruptcy. Graham wrote, "The speculative public is incorrigible. In financial terms it cannot count beyond 3."[47]

In truth, assuming the future will be similar to the past beats a lot of expert forecasts. But it also introduces the risk of overextrapolation and a failure to recognize regression toward the mean. Financial economists suggest that extrapolation plays an important role in asset pricing, including explaining the momentum factor and the inflation and deflation of bubbles.[48] It also offers insight into why investors anticipate high returns after the market's returns have been high, and low returns after the market's returns have been low.[49]

One key feature of pattern recognition is that it is intuitive. Research in cognitive psychology shows that in some cases when an individual realizes their intuition is misguided, they still act on it rather than correcting their error. This is called "acquiescing" to intuition.[50]

For example, in one experiment researchers created a scenario in an American football game where the participant had to choose between punting or going for it on fourth down late in a close game.[51] The analysis showed that going for it had a win probability nine percentage points higher than punting did. Forty percent of the participants had the intuition to punt but understood that the analytics said to go for it. Of that group, 56 percent elected to acquiesce to their intuition and punt anyway.[52]

In the case of acquiescence, individuals are aware that pattern recognition does not offer a reliable answer but nevertheless default to it. They fail to correct what they know to be an error.

How to Improve Pattern Recognition

Acknowledging when pattern recognition is reliable is the first step in trusting its usefulness. Individuals can cultivate pattern recognition in systems that are stable, provide reliable cues, and lend themselves to accurate feedback. Pattern recognition can be alluring but misleading in systems without those traits. The inputs to an investment process can span both systems, so pattern recognition is helpful to fundamental investors in some contexts and unsuitable in others.

Two prerequisites for acquiring intuitive expertise are a stable and linear environment and proper training with inputs that explain what works. Many, if not most, fundamental investors do not meet these basics. They tend to model corporate performance using what psychologists call the "inside view," which focuses on the individual circumstances of a problem and draws heavily on personal understanding. For investors, this is a bottom-up method that considers the firm's specific issues and is guided by the analyst's experience.

A different approach, called the "outside view," is integral to training for pattern recognition. The outside view considers a problem as an instance of a larger reference class. By knowing the outcomes from the reference class, or the base rates, an investor can make informed, albeit probabilistic, assessments about what will come next. This is the goal of quantitative investors and offers insight into how fundamental investors can hone their ability to recognize patterns.

One example is modeling sales growth, which is usually the most important driver of shareholder value.[53] The distribution of sales growth rates tends to be reasonably stable over time, which means it is feasible to place growth expectations in the context of what has happened before. Anticipated growth rates relative to the base rate provide a cue about expectations. Growth that is higher than expected for a company that creates value leads to attractive total shareholder returns. And expected growth versus actual growth offers feedback.

Sales growth rates show substantial regression toward the mean, which says that results that are far from average tend to be followed by outcomes closer to the average. In practical terms, both high and low past growth rates precede growth rates closer to the average for a population of companies. Sales growth rates and how they regress follow patterns that investors can learn to recognize.

The outcomes from M&A are another example of where pattern recognition may be useful, notwithstanding the story in the opening. Historically, most M&A deals have failed to create value for the buyer, as measured by cumulative abnormal stock returns.[54] But there are ways to shade the odds in favor of the buyer, including paying a small premium to acquire the seller, paying for the deal in cash versus stock, and doing deals for businesses that have operations similar to those of the buyer.[55]

Observing the distribution of outcomes within a reference class can provide some insight into how difficult it is to predict patterns. For example, since 1984 the distribution of 10-year sales growth rates for public companies in the U.S. with $5-10 billion of initial sales follows a distribution that resembles the classic bell curve, with a mean and median around 4.5 percent and a standard deviation of 8.5 percent.[56]

But the distribution of book sales follows a power law, where most of the observations have small outcomes and a few observations have large outcomes.[57] For instance, of the 3 million titles offered by booksellers, only a handful sell more than 1 million copies, about 4,000 new titles sell more than 1,000 in a year, and most sell fewer than 100.[58] Outcomes that follow a power law are generally an indication of a wicked environment, where cause and effect are unclear and pattern recognition is hard.

The main challenge in applying base rates effectively is selecting an appropriate reference class. The guidance on how to do so tends to be qualitative.[59] But training intuition, a precursor to useful pattern recognition, almost certainly requires having solid data on the relevant base rate. Cues, causality, and feedback are essential.

There is some risk to learning the wrong lessons from an inappropriate reference class, but in our view the bigger risk is a failure to use base rates in the first place. There are a handful of reasons investors do not use base rates. To start, decision makers trust the inside view as it centers on their analysis and experience. This helps explain acquiescence.

Individuals also see their situation as unique and do not perceive that examining related instances provides insight. Interestingly, most people are better at recognizing when the outside view applies to others than when it applies to themselves. You can relate to this if you have ever quipped to an acquaintance that their home renovation project will take longer and cost more than they have bargained for.[60]

Even in cases when decision makers are willing to use base rates, the data may not be at their fingertips. Few fundamental investors have studied past measures of corporate performance in sufficient detail to prepare their minds to anticipate what might happen in the situation they face. Experience does not offer a simple solution because our memories can capture and retain only a sliver of what has happened.

The bottom line is that fundamental investors can train their ability to recognize patterns under the correct conditions. Data that provide cues and causality, as well having a basis for timely and accurate feedback, are fundamental. The efficacy of pattern recognition is context dependent.

Conclusion

Many fundamental investors rely on pattern recognition as part of their decision-making process. They create plausible stories informed by their experience and memory. But it is important to consider how pattern recognition works to understand its applicability.

Pattern recognition is more effective in stable environments where cause and effect are clear and participants are trained using timely and accurate feedback. This applies in many domains, including sports, music, and chess. Participants in these areas can develop intuitive expertise, an unconscious sense of recognition that leads to superior performance.

Pattern recognition tends to fail in domains where causality and feedback are limited. But that does not stop decision makers from feeling the sense of pattern recognition. Our mental apparatus allows us to see patterns that truly exist as well as to see them when they do not exist.[61]

Distinguishing between experience and expertise is crucial. All experts have experience but not all with experience are experts. The defining feature of an expert is having a predictive model that works. Ample research shows that expert predictions in social, political, and economic realms are poor. Expert views tend to correlate in realms where expert prediction is effective.

This shortcoming is more a reflection of the domain than of the person and underscores the importance of understanding the boundaries of useful prediction. But our minds are keen to go out of bounds, imposing patterns where none exist or acquiescing to our gut reaction even when we know that using explicit analysis can help correct a decision error.

Fundamental investors can build their skill in pattern recognition in certain aspects of the investment process, including assessing fundamental value drivers such as sales growth or judging the stock market's reaction to M&A deals. In both cases, this skill builds on an understanding of base rates and how to use them in prediction.

Investors who want to assess their skills at pattern recognition can maintain a journal and document their intuitions. Done properly, this allows for the measurement of calibration, or how well probabilistic forecasts match the frequency of outcomes. Over time, such an accurate self-assessment can help reveal where and when pattern recognition is accurate and adds value.

Please see Important Disclosures on pages 20-22

Endnotes

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[2] George P. Baker, "Beatrice: A Study in the Creation and Destruction of Value," *Journal of Finance*, Vol. 47, No. 3, July 1992, 1081-1119.

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[4] At the time of this deal, there were two ways to account for an acquisition: pooling and purchase. To simplify greatly, with pooling the balance sheets of the buyer and seller were added together and there was no effect on earnings. With a purchase, any payment above book value was recorded as goodwill, and amortized over a period up to 40 years. In this case there was a negative effect on earnings. In 2001, the Financial Accounting Standards Board (FASB) got rid of pooling as well as the amortization of goodwill. Today companies must only do a periodic check to verify that the carrying value of goodwill is proper and take a write-down if the value is impaired. See Abraham J. Briloff, "Cannibalizing the Transcendent Margin: Reflections on Conglomeration, LBOs, Recapitalizations and Other Manifestations of Corporate Mania," *Financial Analysts Journal*, Vol. 44, No. 3, May-June 1988, 74-80.

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[6] Shortly after the deal, Conagra changed its internal earnings measure to reflect that goodwill is a non-cash and non-economic charge. From the company's 1994 Form 10-K: "During fiscal 1993, we improved our objectives by incorporating a concept called 'cash earnings'—net earnings plus goodwill amortization. Businesses run on cash. The principal source of internally generated cash is net earnings before depreciation of fixed assets and amortization of goodwill. Cash from depreciation is generally needed for replenishment to help maintain a going concern. On the other hand, goodwill represents valuable non-depreciating brands and distribution systems, primarily those we acquired with Beatrice Company in fiscal year 1991. We invest and incur expense throughout the year to maintain and enhance the value of these brands and distribution systems. Consequently, *goodwill amortization is not a true economic cash cost*. It, along with net earnings, is a source of decision cash—cash available to invest in ConAgra's growth and pay dividends." (Emphasis added.)

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[19] For examples of where it works, see Gary Klein, *Intuition at Work: Why Developing Your Gut Instincts Will Make You Better at What You Do* (New York: Currency/Doubleday, 2003). For examples of where it fails, see Daniel Kahneman and Amos Tversky, "Intuitive Prediction: Biases and Corrective Procedures," *Decision Research Technical Report PTR-1042-77-6*, 1977.

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[33] Berkeley J. Dietvorst, and Soaham Bharti, "People Reject Algorithms in Uncertain Decision Domains Because They Have Diminishing Sensitivity to Forecasting Error," *Psychological Science*, Vol. 31, No. 10, October 2020, 1302-1314.

[34] As a slight diversion, the workings of complex adaptive systems are part of the debate about the existence of free will. See Robert M. Sapolsky, *Determined: A Science of Life Without Free Will* (New York: Penguin Press, 2023), 154-202.

[35] "Open Letter to Ben Bernanke," November 15, 2010. See www.wsj.com/articles/BL-REB-12460.

[36] Blake LeBaron, "Financial Market Efficiency in a Coevolutionary Environment," *Proceedings of the Workshop on Simulation of Social Agents: Architectures and Institutions, Argonne National Laboratory and University of Chicago*, October 2000, Argonne 2001, 33 51. LeBaron writes, "During the run-up to a crash, population diversity falls. Agents begin to use very similar trading strategies as their common good performance begins to self-reinforce. This makes the population very brittle, in that a small reduction in the demand for shares could have a strong destabilizing impact on the market. The economic mechanism here is clear. Traders have a hard time finding anyone to sell to in a falling market since everyone else is following very similar strategies. In the Walrasian setup used here, this forces the price to drop by a large magnitude to clear the market. The population homogeneity translates into a reduction in market liquidity."

[37] Keith J. Holyoak and Paul Thagard, *Mental Leaps: Analogy in Creative Thought* (Cambridge, MA: MIT Press, 1995), 15.

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[40] Michael S. Gazzaniga, *Tales from Both Sides of the Brain: A Life in Neuroscience* (New York: Ecco, 2015), 150-153.

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[42] In a coin tossing game that was biased toward heads (60 percent), nearly one-half of the participants bet on tails more than five times in the game and the likelihood of betting on tails increased after a string of heads. See Victor Haghani and Richard Dewey, "Rational Decision Making under Uncertainty: Observed Betting Patterns on a Biased Coin," *Journal of Portfolio Management*, Vol. 43, No. 3, Spring 2017, 2-8. In another experiment, participants learned about marble draws (30 green and 10 red) and then asked to guess the color of additional draws to win money. This group also frequency matched. See Derek J. Koehler and Greta James, "Probability Matching in Choice under Uncertainty: Intuition versus Deliberation," *Cognition*, Vol. 113, No. 1, October 2009, 123-127.

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[44] Jason Zweig, *Your Money and Your Brain: How the New Science of Neuroeconomics Can Help Make You Rich* (New York: Simon & Schuster, 2007), 69-70.

[45] Scott A. Huettel, Peter B. Mack, and Gregory McCarthy, "Perceiving Patterns in Random Series: Dynamic Processing of Sequence in Prefrontal Cortex," *Nature Neuroscience*, Vol. 5, No. 5, May 2002, 485-490.

[46] There were 780 initial public offerings in 1969, the most of any year since 1960. See Roger G. Ibbotson, Jody L. Sindelar, and Jay R. Ritter, "The Market's Problems with the Pricing of Initial Public Offerings," *Journal of Applied Corporate Finance*, Vol. 7, No. 1, Spring 1994, 66-74.

[47] Benjamin Graham, *The Intelligent Investor: A Book of Practical Counsel, Fourth Revised Edition* (New York: Harper & Row, 1973), 245.

[48] Nicholas Barberis, "Psychology-Based Models of Asset Prices and Trading Volume," in *Handbook of Behavioral Economics—Foundations and Applications*, Vol. 1, B. Douglas Bernheim, Stefano DellaVigna and David Laibson, eds. (Amsterdam: North-Holland, 2018), 79-175 and Nicholas Barberis, Robin Greenwood, Lawrence Jin, and Andrei Shleifer, "Extrapolation and Bubbles," *Journal of Financial Economics*, Vol. 129, No. 2, August 2018, 203-227.

[49] Robin Greenwood and Andrei Shleifer, "Expectations of Returns and Expected Returns," *Review of Financial Studies*, Vol. 27, No. 3, March 2014, 714-746.

[50] Jane L. Risen, "Believing What We Do Not Believe: Acquiescence to Superstitious Beliefs and Other Powerful Intuitions," *Psychological Review,* Vol. 123, No. 2, March 2016, 182-207 and Jane L. Risen, "Acquiescing to Intuition: Believing What We Know Isn't So," *Social and Personality Psychology Compass*, Vol. 11, No. 11, November 2017, e12358.

[51] The details do not matter for those who are not familiar with American football. Note only that conventional wisdom and past practice (intuition) would advocate punting and analytics would support going for it.

[52] Daniel K. Walco and Jane L. Risen, "The Empirical Case for Acquiescing to Intuition," *Psychological Science*, Vol. 28, No. 12, December 2017, 1807-1820.

[53] Etienne Theising, Dominik Wied, Daniel Ziggel, "Reference Class Selection in Similarity-Based Forecasting of Corporate Sales Growth, *Journal of Forecasting*, Vol. 42, No. 5, August 2023, 1069-1085.

[54] Mark Sirower and Jeff Weirens, *The Synergy Solution: How Companies Win the Mergers and Acquisitions Game* (Boston, MA: Harvard Business Review Press, 2022), 7.

[55] This is an example of "similarity-based forecasting," where placing different weights on instances within the reference class can sharpen forecasting accuracy. For example, this might benefit an assessment of an M&A deal. See Lovallo, Clarke, and Camerer, "Robust Analogizing and the Outside View."

[56] Michael J. Mauboussin and Dan Callahan, "The Impact of Intangibles on Base Rates," *Consilient Observer: Counterpoint Global Insights*, June 23, 2021.

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