



## *The Art of Algorithmic War*

*If you know your enemies and know yourself, you can win a hundred battles without incurring jeopardy.*

Sun Tzu

In this market age of dark pools, contorted orders and ‘self’-learning machines, the battle not only for alpha but also for simple survival looks more like war than ever before. What can brain science teach Wall Street about both types of knowledge? Do we really know our enemy and have we even considered self-knowledge as potent?

The two interrelate.

Emanuel Derman notes in *Models.Behaving.Badly.* (2012) that “*the movements of stock prices are more like the movements of humans than molecules.*” Realizing that markets are human constructions should have made this observation obvious but as he discusses, modeling market interaction has resulted in artificial and inaccurate explanations of price action. We of course have the observations of Behavioral Finance that catalogue average or typical behaviors, but is describing such phenomenon enough? Even practitioners of Behavioral Finance admit their lack of a coherent theory to explain their data and this fact alone further exacerbates the need for more accurate theories.

In particular, the spectrum of 21<sup>st</sup> century brain science offers a new theory of thinking itself. It differs dramatically from the classic beliefs about reason, logic, feelings and markets. Antonio Damasio, Director of the Brain and Creativity Institute at the University of Southern California first outlined the change in his 1995 book *Descartes’ Error: Emotion, Reason and the Human Brain.* In the almost two decades since Damasio’s groundbreaking work, brain science has continued to deliver more and more evidence that human perception, judgment and behavior emerge from the objects of Sun Tzu’s advice—the social (enemy) and the feeling or emotional context (self).

Thinking about thinking needs to move from overvaluing an individual’s intellectual icing to capitalizing on the chemistry of the cake’s ingredients.

This paper provides a brief overview of key subsets of the current research on perception and judgment and outlines strategies and tactics based on neuroscientific insights for developing more robust models, creating more effective algorithms and instituting more effective risk management approaches. After setting the stage with insights from experimental finance and social neuroscience, the emphasis will turn to improving upon individual risk perception and judgment.

## SOCIAL BRAINS: SOCIAL MARKETS

While it should be obvious that markets are social constructions, their development from what we now know to be socially-mediated brains may not be as clear. For example, in examining the link between brain development and the use of stone tools by humans, Grove and Coward (2008) note that in understanding the development of tools the important factor “is not the individual neuron, nor even necessarily the individual brain, but instead the socio-cognitive context in which brains develop and tools are manufactured and used.” In examining the development of human cognition, Hasson, *et.al.* (2012) argue that “in many cases the neural processes in one brain are coupled to the neural processes in another brain via the transmission of a signal through the environment.” Such coupling via signals—i.e. social interactions—lead “to complex joint behaviors that could not have emerged in isolation.”

Turning again to Derman (2012) and his erudite warning on mistaking the model for the thing being modeled, consider the possibility that the “thing” of markets can also be understood most accurately through the *idea* of a social mechanism. The efforts to interpret social media sentiment via big data reduction equate to a “know your enemy” strategy. A brain science argument can be made however for analyzing the “social” even earlier in the quantitative processes.

Specifically, game theory offers backward induction or beginning at the desired outcome and reversing the moves as a perceptual aid. This means specifically thinking about what developments competitors may be working on. It also goes a step further to imagining how those types of models and algos could impact price action. Justification to go beyond probabilistic tools comes from Bruguier, Quartz and Bossaert’s (2010) experimental finance research. They showed that human brains deliver more accurate price predictions when relying on what neuroscientists call “Theory of Mind”—the innate human ability to predict other people’s future behavior.

Imagine simultaneously playing chess and paintball. It is an apt comparison for the war of markets. The game is or would be mental and physical, strategic and tactical all at the same time. Like the metaphor, our perception and judgment relative to the markets has mental and physical as well as tactical and strategic components. As we will discuss, the physical and emotional are now known to be critical to our best thinking. Engaging in thought experiments that draw on

real-life social competitions can be quite helpful in the idea-generation and in the “what if” testing phases of algo implementation.

Peters (2012) research on the decision making of more numerate versus less numerate individuals suggests that the highly numerate tend to overuse numbers in making decisions. While understandable as a way of reducing the anxiety involved in dealing in less precise factors, ignoring what brain science is delivering about the true importance of the social, feeling and emotional contexts leaves out potentially useful information.

## **WHAT’S IN THE CAKE?**

One of the difficulties in deliberately improving risk decision making is the paradox of the findings from research on the unconscious thought effect (UTE) or what is also known as the deliberation without attention (DWA) phenomenon. Many of us have had the experience of realizing the solution to a decision or other type of problem “out of the blue” when our conscious attention was not focused on that problem. Dijksterhuis (2004) has shown improvements in the results of decisions when the conclusion is drawn after a purposeful period of turning attention elsewhere.

While there are many studies that either confirm or disconfirm his findings, one critically relevant to the risk-management element in the quant’s world comes from medical diagnostics (de Vries *et.al.* 2010). In comparing diagnoses in clinical psychiatric cases, their research suggests that *unconscious* processing significantly increased the correct number of classifications when compared to the process of consciously thinking about the information in the case description.

A second example arises from what is now being recognized as body-based intellect. Called embodied cognition, the field is demonstrating how physical events like tensing one’s muscles (Hung and Labroo, 2011) or standing up straight can increase perseverance on an unanswered problem. Furthermore, in practicality we all know that exercise, for example, helps us think more clearly. Development, testing and re-calibration processes can all benefit from individuals and teams having access to a gym during working hours.

A third area of research that contradicts Wall Street’s thinking is how our brains deal with and actually rely on fear. First from a physiological point of view, the conventional wisdom in brain

science and psychology holds that fear is mediated by the amygdalae—the almond shaped structures on either side of our brains. Feinstein, *et. al.* (2013) recently found however that with certain types of fear such as internal threats, the amygdala may be irrelevant. This changes everything brain science thought it knew about how fear occurs. Further research by Cunningham and Brosch (2012) suggests that instead these structures play a role in deciphering meaning for *any* sensory input.

Given the growing acceptance that thinking is the product of interactivity between the brain, body, neuroelectrochemicals and the social environment, the latter also speaks to the emerging controversy over the role of testosterone in building over-confidence amongst traders. Coates and Herbert (2008) found that periods of success breed high testosterone which in turn appears correlated with excessive risk taking. Conversely, Stanton *et. al.* (2011) found that both high *and* low testosterone individuals displayed *less* risk aversion.

## **THE CONFIDENCE FACTOR**

Damasio named his ground-breaking book, *Descartes' Error* because Descartes, the 17<sup>th</sup> century philosopher had declared “I think therefore I am.” Damasio’s research team was clearly demonstrating the reality to be different - “I *feel* therefore I am” and so began the trilogy of *Descartes' Error*, *The Feeling of What Happens* and *Looking for Spinoza*. The essence of human consciousness, according to Damasio, is not cognition; it is feeling.

Damasio has continued to be a leader in this new view of thinking giving presentations entitled “The Primacy of Feelings” at places like the annual meeting of The Society for Neuroeconomics in 2011.

Damasio and Gil Carvalho (2013) summarized the new view of human feelings:

Feelings ... signify physiological needs like hunger, tissue issues like pain, threats in fear or anger and social meaning in compassion, gratitude or love. Feelings constitute a crucial component of life - from the simple to the complex. Their substrates can be found at all levels of the human nervous system from individual neurons to the highest cerebral cortices.

And Damasio is a far from alone. Widely regarded Cal-Tech Professor Colin Camerer and his colleagues stated in their meta-analysis of neuroeconomics published in the *Journal of Economic Literature* (2005) “it is not enough to know what should be done, one must also feel it.”

In other words, in brain science circles, feelings and emotions have a completely different role than they do on Wall Street, where they are shunned or worse, ignored. First and foremost, researchers now agree that feelings imbue every single decision. Put another way, no neuroscientist would bother to advocate for emotionless decisions because they know such a thing to be impossible

## **WHAT ARE FEELINGS FOR AND WHERE DO THEY COME FROM**

Feldman-Barrett and Bliss-Moreau penned “Affect as a Psychological Primitive” (2009) to say that not only are feelings (called “affect” in academia) primary to all mental states but that our whole understanding of emotion, a subset, has been wrong. As proponents of what is called “Psychological Constructionism”, they reject the widely used categorization of the five basic emotions popularized by Ekman (1992) (and popularized in the TV show *Lie to Me*). And in other meta-analytic work, Feldman Barrett and Wager (2006) suggest that the only *universally* valid parsing of emotional experience is like/dislike or want/not want—what psychologists term “approach/avoidance.”

In a meta-analytic review of the brain basis for emotion, Lindquist *et. al.* (2012) concluded:

We found little evidence that discrete emotion categories can be consistently and specifically localized to distinct brain regions. ... Instead, we found evidence that is consistent with a psychological constructionist approach to the mind: A set of interacting brain regions commonly involved in basic psychological operations of both an emotional and non-emotional nature are active during emotion experience and perception ....

Agreeing with the findings of broad interactivity across brain regions, structures and neurochemicals, Anderson, Kinnison and Pessoa (2013) note that the ubiquitous reporting of this or that brain structure or hormone as being singularly responsible for a given emotional or cognitive experience misleads the public as to what is really going on.

## **FEELINGS AS DATA**

How can this research be applied to improving the processes of building tools for trading and financial decision making? How can knowing yourself add to your ability to analyze the characteristics of a market? Two relatively easy ways come to mind when we think of the observed aversion to ambiguity and the tendency to confirm existing beliefs. Called the ambiguity aversion and confirmation bias respectively, these two Behavioral Finance

observations can be recognized earlier in the process if one is naturally treating their feelings as data. In other words, a practitioner can sense their desire to reduce the ambiguity or prove their first idea correct.

Next, our views on how feelings *can* work need to be changed. The aforementioned substantive misunderstanding stems partially from failing to see the difference between a feeling itself and the doing of or acting on the feeling. Underlying most of the non-scientific discussion on feelings and emotions is the assumption that a feeling or an emotion *automatically* becomes an action. Logically, this is simply untrue. We feel things that they we don't act on all of the time. We don't punch our boss or grab and kiss the stranger in line behind us.

Why are we able to do that? In those social situations, expectations of proper behavior and potential punishment lead us to treat the feeling as information. The fact that our boss is being unfair or the person behind us is immensely attractive gets treated like data—which is how the brain is using it—and analyzed. A particular action may or may not occur—depending on the interpretation of the incoming data.

One area in which even analytical types are comfortable with feelings is when talking about confidence or conviction. Even IBM's Watson relied on an algo-generated “feeling” of confidence. Wall Street analysts and traders describe their conviction or lack thereof in much of what they do. Confidence is the feeling—or at least one of a broad spectrum of feelings—that must be present to make a decision of any type. If one doesn't have some level of confidence that one choice is better than an alternative, the person will loop endlessly through the pluses and minuses for either choice.

This is consistent with the idea that in their pure form, feelings and emotions are meant to inform us. Without realizing it, Wall Street adds emotional information to analytic reports.

From the brain's point of view it appears that when we acknowledge and identify feelings, our psyches appear to be satisfied that the protective warning has been heard and as a result we have more choices of behaviors.

## **THE FRACTAL PSYCHE**

The trick, which admittedly is no small feat whatsoever, lies in distinguishing between the feelings that provide valid assessments of the current situation versus those feelings that are based on patterns in the past that create expectations of the future.

The latter appear to be either literally fractal or so similar that the idea of fractal patterns within the psyche provides a spot-on metaphor. Pezard and Nandrino (2001) in fact noted over a decade ago that research results of applying Chaos Theory to psychology, of which fractals are a part, reveals the concepts to be more than simply metaphorical.

Additional research into the possibility of fractal geometry applying to the brain and thinking comes from Dixon, Holden, Mirman, and Stephen (2012) who said:

Changes in cognitive performance exhibit a fractal relationship between size and time scale. These fractal fluctuations reflect the flow of energy at all scales governing cognition. ... The cognitive system exhibits not just a single power-law relationship ... but actually exhibits many power-law relationships, whether over time or space. This change in fractal scaling, that is, multifractality, provides new insights into changes in energy flow through the cognitive system.

For an example of how in fact the brain may mediate a fractal-like fear, Visser, *et. al.* (2013) discovered that the way a person experiences particular phobias, say a fall from a horse and a lingering fear of horses, could be predicted by how the brain was firing at the time of the initial event. In other words, past neurological activity becomes the basis for future experience.

Theoretically, this could be the substrate for repetitive perceptions and expectations that appear to be fractal.

Regardless of whether perception proves to be verifiably fractal or simply better understood through the adoption of the metaphor, separating this subjective experience of emotion from the larger mental database of informational feelings offers a powerful mechanism for knowing oneself and in turn reducing mistakes.

## **(IRONIC) TOOLS FOR AVOIDING BIASES**

How does a “quant” or a team of quants take brain science and use it in the context of Sun Tzu’s directives—know your enemy and know yourself? Particularly how does one do the latter when so much of perception appears to be below our conscious levels?



From the time of Freud, both body and feelings have been known to offer indicators of what might be intellectually unavailable. In a summary article reviewing what brain science calls “embodied cognition”, Reimann *et. al.* (2012) seek to answer if “emotions function as the bridge between bodily perceptions and downstream cognitive processing such as judgment and choice ...” and it appears that the answer is “Yes.”

In the world of Wall Street, where the typical techniques are quantitative—statistical time series, for example—practitioners need *first to believe* that capturing and categorizing the seemingly messy and disorganized data of feelings will bear fruit. This brings us back to Sun Tzu and the question of knowing oneself as well as to Derman and the sheer volume of text he used in addressing the subject of emotion in *Models.Behaving.Badly*.

To the forward-thinking practitioners who seek to move beyond misconceptions about feelings and emotions, the next steps include creating language, categories, definitions and tools. Each is needed to be able to capitalize on feelings when brainstorming about the unexpected – a necessary process in algos for proprietary trading if not in agency models and the question of the next dark pool’s behavior.

In the realm of language and definitions, feelings include a sense of something like intuition (which can be considered unconscious pattern recognition or experiential learning) and emotional indicators of threat in the form of fear or anger.

Changing one’s own thinking processes to habitually include detection and analysis of known relevant feelings and emotions serves two purposes. First, the odds of a feeling being unintentionally acted on go down. This is risk management. Second, this new learning begins to open up a wider door both to utilize intuition—unconscious pattern recognition—and to gain an edge on those agents who are not employing this tool.

## **QUESTIONS TO INCORPORATE**

A number of tools are available to benefit from the information that feelings and emotions can provide. The following questions can and should become not only culturally acceptable but *de rigueur* in any question requiring judgment. Two examples from the systematic trading world are what is the proper period for implied volatility is and what definitely qualifies as evidence that an algorithm is failing?

Recognizing one's emotional state at any given moment and what one's pattern is over time will create self-knowledge. Likewise, implementing the following three feeling-analytic questions on a systematic basis at the group level will improve group problem solving and avert groupthink.

The first can involve an eight-point scale ranging from panic to arrogance.

### **Panic–Fear–Anxiety–Doubt–Tolerate–Optimistic–Confidence–Arrogance**

Good decisions typically emerge when feeling contexts converge between doubt and confidence.

The second should be a four point breakdown of one specific type of fear and anxiety. It relies on regret theory originally outlined by Loomes and Sudgen (1982) and is meant to uncover the normal fear of future regret (FOFR) that is an integral part of many decisions—particularly those made in the Knightian uncertainty of trading. Such a breakdown specifically can disrupt a detrimental instantiation of the competitive instinct in which the desire to win becomes secondary to accomplishing the true goal.

### **No FOFR–Detectable FOFR–Palpable FOFR–Intense FOFR**

The latter two—palpable and intense—signal a lack of objectivity.

The last, and potentially most powerful, is again a simple scale for the common fractally-patterned contexts quants often operate in. It rotates around the ideas of the desire to be seen as smart and or “right.” The recommended approach is to *assume* that at moderate levels this is motivating but like with FOFR, intensities beyond the lowest (“detectable”) equate to the potential for choosing actions not based on the most relevant data but on extraneous motivations.

In this case, simply ranking and admitting to the desire to be correct can go a long way to averting the negative consequences. A simple, at least in terms of language if not in terms of implementation, desire scale could look like:

### **Interested–Concerned–Worried–Obsessed–Angry**

Anything beyond “interested” should be further examined.

Each question combined with the intentional technique of verbalizing feelings is likely to have great bottom-line benefits. If an individual or a leader of a team can repeatedly garner the most accurate answer to each, they automatically build the weapon of self-knowledge and in doing so will consistently reveal the circumstances that often obscure potential mistakes therefore avoiding them before they happen.



When the step of automatically including this data in analyses preceding judgment calls becomes common-place, a team or individual can then add the Levels of Emotional Awareness Scale developed by Richard Lane (1990). This involves grading answers according to the complexity of the description of the feeling. An electronic version is in development at the University of Arizona and further information on how to implement this in a group will be added in future versions of this paper.

## **PROPER HANDLING OF THE ANSWERS**

In the last surprising finding to be covered in this brief synopsis, subjects who verbalized their feelings in a completely unedited way were least likely to act out (or “do”) those feelings. A number of studies report this but the most recent (Kircanski *et. al.* 2012), analyzed the behavior of a group of people suffering from arachnophobia. In researching their reaction to a tarantula, the academics found that those who verbalized their fears in an unedited manner were most able to actually stay near and even touch the tarantula. In contrast, the groups using cognitive strategies such as reappraisal were less likely to show any behavior change. In other words, feeling and describing the feeling had more impact than using the intellect to modify behavior

## **CONCLUDING THOUGHTS**

In 2012, the top executive at an agency quant shop remarked to us the paraphrase “*we’ve gotten to the point where the algos are just going to keep fighting it out so where do we go next?*”

Our answer is the proverbial “it’s simple but not easy.” Rethinking thinking – and then acting on that new understanding – will provide a measurable competitive advantage. We recognize however that the mistaken merger between feelings and actions won’t be easily undone.

It’s understandably tough, as the Peters research intimated, for those used to being the smartest mathematicians in their circles to begin to think in terms of what do they feel and where could they be wrong. It’s even tougher to imagine that phenomena that seem as ephemeral and untrustworthy as feelings and emotions could actually be useful.

Nevertheless, it is true. And in fact, sort of like the emperor with no clothes, on some level, almost everyone actually knows it.

The question isn't really is there a role for analyzing fear, confidence and the desire to be right but how do we do that on a systematic basis? Decades of discarding these critical dimensions of cognition into the evolutionary archives haven't even allowed us to even try.

The identification and articulation tools here may seem elementary. Their power lies in their simplicity and the associated discourse. Additional research on the processes of social interaction is demonstrating how talking actually does expand perception. Where teams are able to discuss the individual inputs of feeling contexts, they will find they more quickly uncover solutions and more efficiently generate creativity that matches the ever changing mood of the markets and the algos that trade them.

Our brains and our thinking are appearing to be emergent from something that looks like a two-dimensional system where the x-axis corresponds to social inputs (from conception, through childhood, education and experience) and the y-axis to our feeling and emotional patterns that respond to the social inputs. The tool of markets, our methods for interacting with them and our reactions to our results occur within the contexts of these two axes. As we develop ways to understand their influence as data, we will likewise learn to better understand both our enemies and ourselves <sup>i</sup>



## ABOUT THE AUTHORS

Denise Shull  
President and Founder  
[DS@TheReThinkGroup.Net](mailto:DS@TheReThinkGroup.Net)  
212.688.1340

Ms. Shull founded The ReThink Group in late 2003 to combine her experience in managing trading desks, trading proprietary money and studying neuroscience in the service of better risk decisions. She has subsequently educated thousands of traders across the globe and penned *Market Mind Games, A Radical Psychology of Investing, Trading & Risk*.

Bill Long  
Managing Director and Contributing Author  
[WTL@TheReThinkGroup.Net](mailto:WTL@TheReThinkGroup.Net)  
918.793.4782

Mr. Long provides portfolio construction, manager selection and strategy consulting services to select sources of capital. He began his career as a Federal Reserve economist and took a turn into high-tech as the leader of a team developing proprietary analytical software for KPMG before returning to finance as part of the Institutional Strategies group at Bear Stearns. He was also Director of Manager Research at Asset Alliance where he interviewed over 200 hedge fund managers.

## BIBLIOGRAPHY

- Anderson, Michael L., Josh Kinnison, and Luiz Pessoa. 2013. "Describing Functional Diversity of Brain Regions and Brain Networks." *NeuroImage* 73:0, 50–58.
- Barrett, Lisa Feldman, and Eliza Bliss-Moreau. 2009. "Affect as a Psychological Primitive." *Advances in Experimental Social Psychology* 41: 167–218.
- Barrett, Lisa Feldman, and Tor D. Wager. "The Structure of Emotion Evidence From Neuroimaging Studies." *Current Directions in Psychological Science* 15, no. 2 (2006): 79-83.
- Bruguier, Antoine J., Steven R. Quartz, and Peter Bossaerts. 2010. "Exploring the Nature of 'Trader Intuition'." *The Journal of Finance* 65 (5): 1703–1723.
- Camerer, Colin, George Loewenstein, and Drazen Prelec. 2005. "Neuroeconomics: How Neuroscience Can Inform Economics." *Journal of Economic Literature* 43 (1): 9–64.
- Coates, J. M., and J. Herbert. 2008. "Endogenous Steroids and Financial Risk Taking on a London Trading Floor." *Proceedings of the National Academy of Sciences* 105 (16) (April 22): 6167–6172.
- Cunningham, William A., and Tobias Brosch. 2012. "Motivational Salience Amygdala Tuning From Traits, Needs, Values, and Goals." *Current Directions in Psychological Science* 21:1, 54–59.
- Damasio, Antonio, and Gil B. Carvalho. 2013. "The Nature of Feelings: Evolutionary and Neurobiological Origins." *Nature Reviews Neuroscience* 14 (2) (February): 143–152. doi:10.1038/nrn3403.
- Damasio, Antonio. 1995. *Descartes' error: Emotion, reason, and the human brain*. Penguin Books.
- Derman, Emanuel. 2011. *Models.Behaving.Badly.: Why Confusing Illusion with Reality Can Lead to Disaster on Wall Street and in Life*. Free Press.
- De Vries, Marieke, Cilia L. M. Witteman, Rob W. Holland, and Ap Dijksterhuis. 2010. "The Unconscious Thought Effect in Clinical Decision Making: An Example in Diagnosis." *Medical Decision Making* 30 (5) (September 1): 578–581.
- Dijksterhuis, Ap, and Loran F. Nordgren. 2006. "A Theory of Unconscious Thought." *Perspectives on Psychological Science* 1 (2): 95–109.
- Ekman, Paul. 1992. "An Argument for Basic Emotions." *Cognition & Emotion* 6 (3-4): 169–200.
- Feinstein, Justin S, Colin Buzza, Rene Hurlemann, Robin L Follmer, Nader S Dahdaleh, William H Coryell, Michael J Welsh, Daniel Tranel, and John A Wemmie. 2013. "Fear and Panic in Humans with Bilateral Amygdala Damage." *Nat Neurosci* 16 (3) (March): 270–272. doi:10.1038/nn.3323.
- Grove, Matt, and Fiona Coward. 2008. "From Individual Neurons to Social Brains." *Cambridge Archaeological Journal* 18 (3): 387–400.
- Hasson, Uri, Asif A. Ghazanfar, Bruno Galantucci, Simon Garrod, and Christian Keysers. 2012. "Brain-to-brain Coupling: a Mechanism for Creating and Sharing a Social World." *Trends in Cognitive Sciences*.

- Hung, Iris W., and Aparna A. Labroo. 2011. "From Firm Muscles to Firm Willpower: Understanding the Role of Embodied Cognition in Self-regulation." *Journal of Consumer Research* 37 (6): 1046–1064.
- Kircanski, Katharina, Matthew D. Lieberman, and Michelle G. Craske. 2012. "Feelings Into Words Contributions of Language to Exposure Therapy." *Psychological Science*.23:10, 1086–1091.
- Lane, Richard D., Donald M. Quinlan, Gary E. Schwartz, Pamela A. Walker, and Sharon B. Zeitlin. 1990. "The Levels of Emotional Awareness Scale: A Cognitive-developmental Measure of Emotion." *Journal of Personality Assessment* 55 (1-2): 124–134.
- Lindquist, Kristen A., Tor D. Wager, Hedy Kober, Eliza Bliss-Moreau, and Lisa Feldman Barrett. 2012. "The Brain Basis of Emotion: A Meta-analytic Review." *Behavioral and Brain Sciences* 35 (03): 121–143.
- Loomes, Graham, and Robert Sugden. 1982. "Regret Theory: An Alternative Theory of Rational Choice Under Uncertainty." *The Economic Journal* 92 (368): 805–824.
- Peters, Ellen. 2012. "Beyond Comprehension The Role of Numeracy in Judgments and Decisions." *Current Directions in Psychological Science* 21 (1): 31–35.
- Pezard, L., and J. L. Nandrino. 2001. "Dynamic Paradigm in Psychopathology: 'chaos Theory', from Physics to Psychiatry." *Encephale* 27 (3): 260–8.
- Reimann, Martin, Wilko Feye, Alan J. Malter, Joshua M. Ackerman, Raquel Castaño, Nitika Garg, Robert Kreuzbauer, Aparna A. Labroo, Angela Y. Lee, Maureen Morrin, Gergan Y. Nenkov, Jesper H. Nielsen, Maria Perez, Gratiana Pol, Jose Antonia Rosa, Carolyn Yoon, and Chen-Bo Zhong. 2012. "Embodiment in Judgment and Choice." *Journal of Neuroscience, Psychology, and Economics* 5:2, 104-123
- Stanton, Steven J., O'Dhaniel A. Mullette-Gillman, R. Edward McLaurin, Cynthia M. Kuhn, Kevin S. LaBar, Michael L. Platt, and Scott A. Huettel. 2011. "Low- and High-Testosterone Individuals Exhibit Decreased Aversion to Economic Risk." *Psychological Science* 22:4, 447–453.
- Visser, Renee M, H Steven Scholte, Tinka Beemsterboer, and Merel Kindt. 2013. "Neural Pattern Similarity Predicts Long-term Fear Memory." *Nature Neuroscience* advance online publication (February 24).

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<sup>i</sup> Portions of the information in this paper can also be found in a chapter written by Denise Shull and containing case studies on "quants" by two co-authors, Drs. Andrew Menaker and Ken Celiano, for the upcoming book *Investor Behavior: The Psychology of Financial Planning and Investing* edited by Victor Riccardi and H. Kent Baker and to be published by Wiley in 2014.