

Psychology and Neurophysiology of Financial Decision-Making

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Some time ago at MIT



Presentation outline

- Behavioral vs. traditional finance
- Physiology studies (incl. JOCN, 2002)
 - Real-time physiological recordings
 - Professional institutional traders
 - Short time-scale – minutes / hours
- On-line study (AER, 2005)
 - On-line questionnaires
 - Serious day-traders
 - Large time-scale – days / weeks
- Conclusions



Behavioral vs. traditional finance

Traditional finance (and economics):

- Humans are selfish and smart – they maximize wealth via optimization
- Milton Friedman, Eugene Fama
- People are rational
- Financial markets are efficient
- Many good theories

Behavioral finance (and economics):

- Humans are nicer and dumber – their cognitive abilities are limited
- Richard Thaler, Daniel Kahneman
- People are irrational
- Financial markets are not efficient
- Almost no theories

● ● ● | Rationality and the environment

- Why behavior is often irrational?
- Evolution shaped the behavior such that it was rational in a different environment
- The “old” environment, where people lived 10,000 and more years ago
- Things changed so rapidly that the evolution did not have the time to adapt human behavior to the “new” environment
- In order to truly understand human behavior in the financial marketplace we need to look at both the behavior and the environment
- Most of the traditional finance until the emergence of the behavioral finance largely ignored the actual behavior
- Most of the behavioral finance work until a few years ago largely ignored the connection with the environment

● ● ● | The “new” behavioral finance

Understanding the reasons for patterns of behavior:

- Ultimate vs. Proximal mechanisms:
 - Ultimate – body needs high calories that can be quickly received from glucose
 - Proximal – sweetness of sugar attracts to high-glucose foods

In our research we focus on emotional mechanisms:

- Are emotions among the key proximal mechanisms driving economic decisions?
- How emotional mechanisms have adapted to the modern environment – the financial marketplace?

● ● ● | Two themes of research

- Understanding the mechanisms behind the economic behavior of individual market participants:
 - What role do emotions play in the decision process?
 - How risk-taking behavior depends on the emotional state?
- How well are behavioral mechanisms adapted to succeeding in the modern financial marketplace:
 - How emotions affect trading profit and loss?
 - Is there any difference in physiology for good and bad performance?

● ● ● | Pilot study in Boston

(Andrew W. Lo and Dmitry Repin, 2002)

- Field study at a major Boston financial institution
- Can emotions be detected from physiological responses in a field study?
- Is there any connection between events in the financial markets and physiological responses?

Motivation

Why emotions are important in trading?

o Rogue traders:

Nicholas Leeson	\$1.4 billion	Nikkei	Barings
Toshihide Iguchi	\$1.1 billion	T-bonds	Daiwa
Robert Citron	\$2 billion	Bonds	Orange County
David Askin	\$500 million	Mortgages	Granite Fund

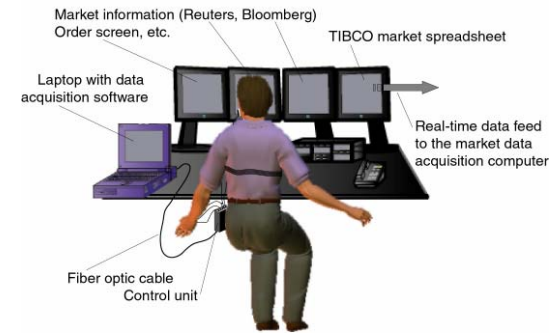
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o Anything else?

- "Intuition"

Experimental site

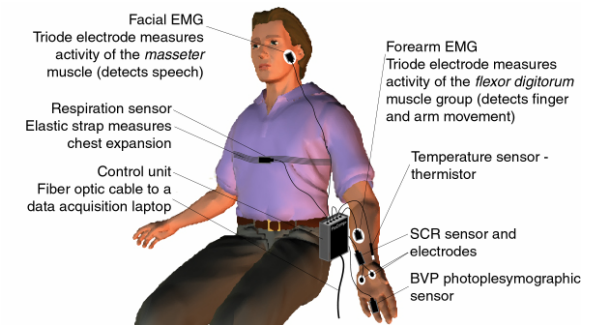
- FX and Interest-Rate Derivatives Desk, 90 traders
- Subjects: 10 traders, 5 retail, 3 FX, 2 derivatives
- 49–83 minutes per session, 8am to 5pm



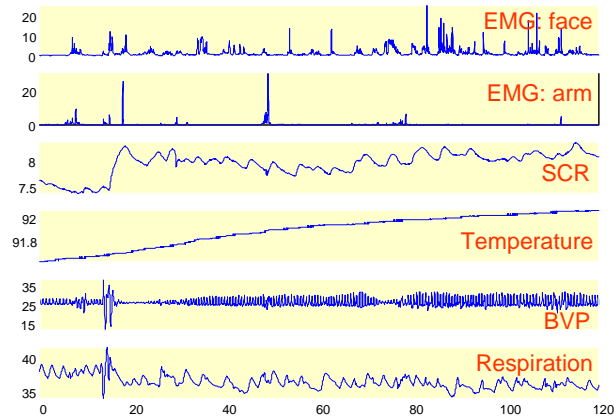
Measurements on the trading floor during normal work hours



Experimental setup



Raw physiological data



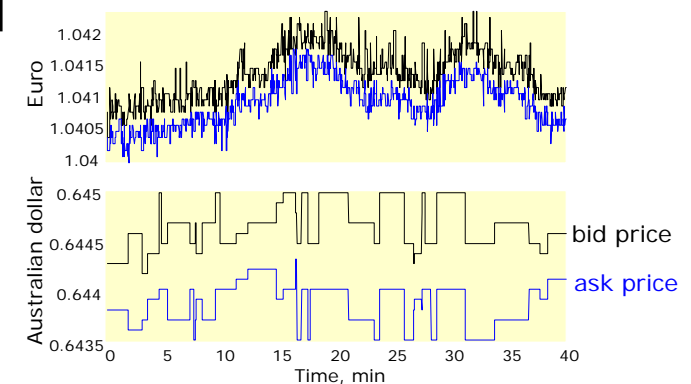
Experimental data analysis

- Measure real-time physiological data
- Collect real-time financial data
- Filter out “artifacts” in physiology data
- Construct “Feature Vectors” around financial events
- Do financial events imply significant changes in subjects’ physiology?
- Stratify by securities, experience, etc.

Physiology data extraction

- Event Feature Vector (± 10 -sec around and event):
 - Times and amplitudes of SCR
 - Average heart rate (3-sec averages)
 - Average respiration rate (5-sec averages)
 - BVP and respiration amplitudes
 - TMP changes (10-sec lag)
- Control Feature Vector (10-sec with no events):
 - Same variables

Market data

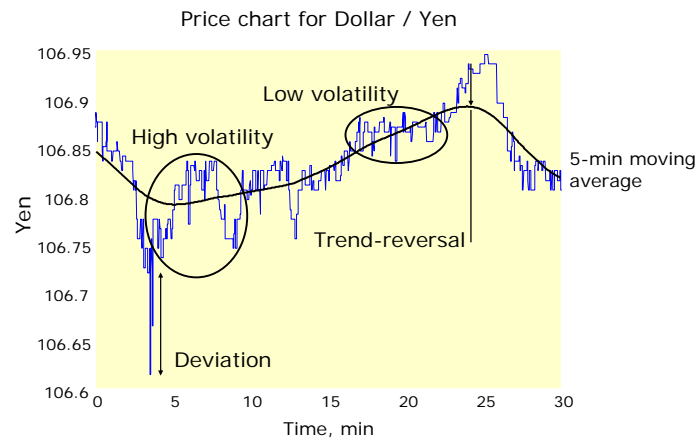


$$\text{price} = (\text{ask} + \text{bid})/2$$

$$\text{spread} = (\text{ask} - \text{bid})$$

$$\text{return} = (\text{price}(t) - \text{price}(t-1))/\text{price}(t-1) \cdot 100\%$$

Market event detection



Pilot study results

- Less experienced traders exhibit significant correlations between physiological responses and short-term market events than more experienced traders

Physiology Features	High Experience						Low or Moderate Experience					
	Market Events						Market Events					
	DEV. Price	DEV. Spread	DEV. Return	TRV. Price	TRV. Spread	VOL. Maximum	DEV. Price	DEV. Spread	DEV. Return	TRV. Price	TRV. Spread	VOL. Maximum
Number of SCR Responses	0.561	1.228	-0.221	-1.261	0.184	2.081	2.636	0.123	2.752	2.170	-0.665	-0.688
Average SCR Amplitude	0.030	0.344	0.744	-1.340	1.149	0.904	0.756	1.578	-1.265	-1.947	-0.012	-0.615
Average Heart Rate	0.449	1.886	-1.797	-1.635	1.836	-2.018	1.310	0.051	-0.382	-1.106	-0.311	1.283
Average BVP Amplitude Relative to Local Baseline	-0.061	-0.747	0.334	0.015	0.164	2.623	-0.204	-1.775	0.875	1.736	-1.289	2.708
Average BVP Amplitude Relative to Local Baseline	-2.529	-1.367	1.590	1.110	-1.165	2.301	1.917	-2.664	1.884	2.082	-1.759	2.758
Number of Temperature Jumps	-1.010	-1.435	NA	NA	NA	1.644	0.837	2.902	1.145	2.445	2.633	-3.213
Average Respiration Rate	-1.556	1.109	0.121	0.866	-0.102	0.093	0.079	-0.552	0.323	-0.631	-2.170	-1.528
Average Respiration Amplitude	1.087	0.265	-1.777	-0.657	0.121	-0.607	-2.749	-1.319	2.142	0.055	-2.832	-4.533

Pilot study conclusions

- Real-time physiological measurements in a live trading environment are possible
- Equipment did not interfere with traders' activities
- Variability in measured characteristics seems plausible
- Likelihood that financial risk processing is related to emotional states as reflected in physiological responses
- Data too coarse for any additional inferences

Boston Stock Exchange (BSE) study

(Andrew W. Lo and Dmitry Repin)

- Does physiology in general reflect trading performance?
- Is there a physiological signature of a "bad" trade or a "good" trade?
- Do emotions help or get in a way of a trading process?

BSE overview

- Regional stock exchange, founded 1834
- 200 Seats, 45MM shares/day, 68,000 trades/day
- Subjects: 8 specialists
- 90-100 minutes per session, 9:30am to ~11am



Updated physiology setup

- Galvanic Skin Response (SCR) on the palm
- Blood Volume Pulse (BVP) taken through photoplethysmography on the thumb (BVP)
- Temperature (TMP1) on the Index Finger
- Temperature (TMP2) on the forehead midway between eyebrow and hairline above the left pupil
- Electrocardiogram (ECG)
- Electroencephalogram (EEG)
- Electromyogram (EMG1) on underside of wrist on Flexor Digitorum
- Electromyogram (EMG2) on Trapezius muscle group on the back of the shoulder

Positive vs. negative P-n-L

- Tension
 - Negative P-n-L response is elevated
 - Positive P-n-L response are similar to the baseline.
- Forehead Temperature
 - Positive P-n-L responses have a higher forehead temperature than negative P-n-L
 - Negative P-n-L responses tend to exhibit an increase in temperature
- Heart Rate (BVP & ECG)
 - Higher than baseline for negative P-n-L
 - Positive P-n-L responses are similar to the baseline
- Heart Rate Variability
 - Both positive and negative P-n-L responses show increased heart rate deceleration

BSE study conclusions

- Short-term effects are generally indistinguishable from each other
- As a result, financial decision making in the short term has minimal effect on the observed physiology
- Long-term effects are noticeable and significant
- For the sample set of market makers, it takes more than a single event to affect a change in physiology
- Longer periods of time are required to enter "physiological zones" where events begin to affect physiological changes



Fear and Greed in Financial Markets: A Clinical Study of Day-Traders (AER, 2005)

(Andrew W. Lo, Dmitry Repin & Brett Steenbarger)

- What is the connection between the trader's emotions and performance?
- Is there a “successful trader” personality type?
- Can emotions, measured through on-line questionnaires, help to understanding financial risk-taking and economic behavior in general?



Participants

- Participants in on-line training program offered by Linda Bradford Raschke
- Demographics:
 - 80 subjects, 57 male, 7 female
 - Ages 24 to 70, Median 45
 - Account sizes \$200 to \$1.8MM, Median \$35K
 - Trading experience: Median 3 years
 - 49 full-time traders
 - 30 with trading as primary personal income
 - 24 with trading as primary household income
 - Five weeks (July 7 to August 9, 2002 – S&P500 dropped some 20%)



Questionnaires

Subjects asked to complete following surveys:

- Initial:
 1. Personality traits (IPIP-NEO) survey
 2. Zung Depression (SDS) and Anxiety (SAS) surveys
 3. Demographics survey
- Daily (five weeks):
 1. Emotional state (UWIST MACL) survey
 2. Trading performance
- Final:
 1. Zung Depression (SDS) and Anxiety (SAS) surveys
 2. Internality, Powerful Others and Chance (IPC) survey



Assumptions

Field study:

- No control over the experimental stimuli → Cannot counterbalance “good” and “bad” market conditions
- Traders, whose risk-taking decisions on average were more successful, would demonstrate better overall risk-adjusted trading profits over the period of the study

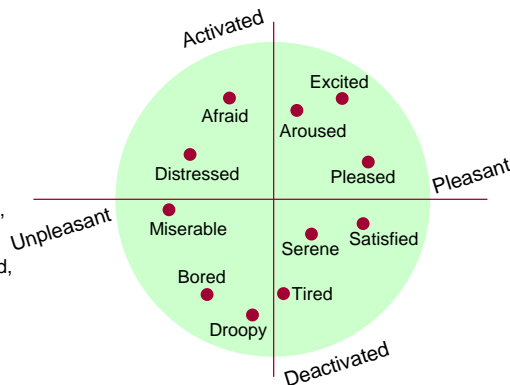
On-line data collection:

- Complete anonymity → Unbiased response
- Little control over response exact timing → Unknown lag between acts of trading and reporting emotions

Experimental design

- Pleasant:** happy, pleased, content
- Unpleasant:** miserable, troubled, unhappy
- Activated:** aroused, alert, hyperactivated
- Deactivated:** sleepy, still, quiet
- Unpleasant Activated:** distressed, upset, guilty, scared, hostile, irritable, ashamed, nervous, jittery, afraid
- Pleasant Deactivated:** relaxed, at rest, serene, calm, at ease
- Pleasant Activated:** interested, excited, strong, enthusiastic, proud, inspired, determined, attentive, active
- Unpleasant Deactivated:** tired, sluggish, droopy, dull, drowsy, bored

Emotional Categories: An Emotional Circumplex model representation



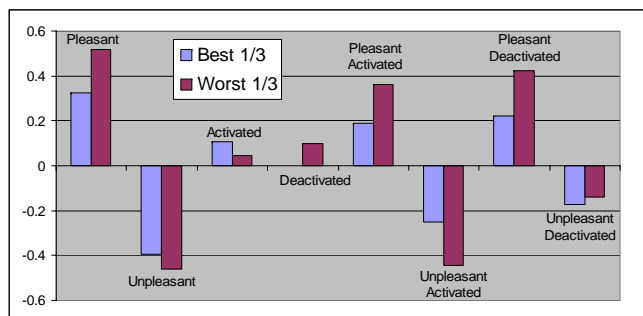
Results: Emotional states

Correlation between P-n-L and emotional state

Sample	Pleasant	Unpleasant	Activated	Deactivated	Pleasant Activated	Unpleasant Activated	Pleasant Deactivated	Unpleasant Deactivated
All Traders	37.5	-31.7	9.5	4.7	30.0	-27.5	25.8	-13.9
p-value	< .01	< .01	1.4	22.6	< .01	< .01	< .01	0.0
Top 1/3	32.4	-39.3	10.5	-0.2	19.1	-25.2	22.1	-17.4
p-value	< .01	< .01	19.7	98.1	1.8	0.2	0.6	3.2
Bottom 1/3	52.0	-46.2	4.5	9.8	36.0	-44.4	42.5	-13.9
p-value	< .01	< .01	50.8	15.0	< .01	< .01	< .01	4.0

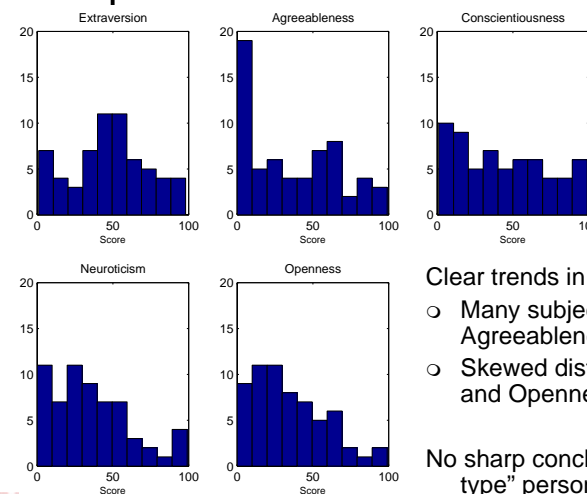
- Pleasant and Unpleasant most highly correlated
- High correlation with valence
- Little correlation with arousal
- Cause-and-effect unclear

Results: Emotional states



- Top performers seem less emotionally affected

Results: Personality traits



Clear trends in personality data:

- Many subjects are low on Agreeableness
- Skewed distributions for Neuroticism and Openness

No sharp conclusions regarding "trader type" personality

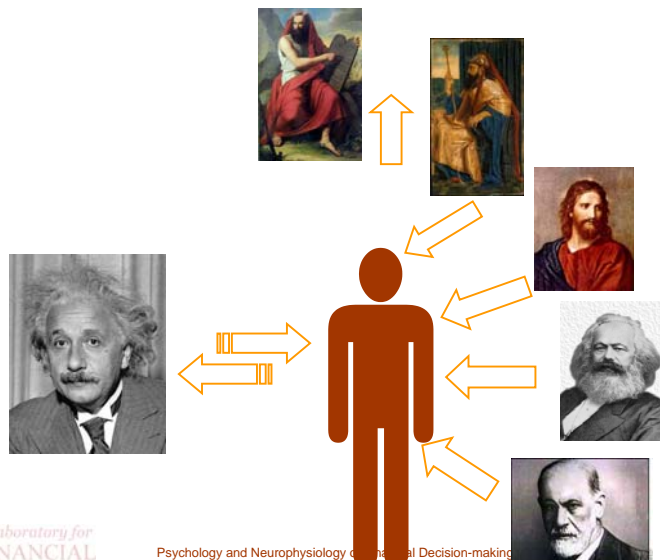
● ● ● | Fear and Greed study conclusions

- Traditional personality assessment may not capture key individual differences related to trading performance
- Emotional Reactivity is likely to be among the most important “traits”
- Trading “traits” may not be as stable through lifetime as general personality traits (like Extraversion, etc.)
- Different personality types can learn to perform well at trading through adaptation

● ● ● | Emotions are essential for rational behavior in *this* environment

- Neurological evidence (Damasio, 1994)
 - Patient “Elliot” → “Irrational” behavior after frontal lobe damage
- Clinical psychology evidence (Steenbarger, 2003)
 - Case-studies linking emotions and trading performance
- Psychophysiological evidence (Lo & Repin, 2002; in progress)
 - Emotions are involved even in case of professional DM
 - Emotions are markers of performance
- Survey evidence (Lo, Repin, & Steenbarger, 2005)
 - Emotional composition is correlated with trading performance
- **The Adaptive Markets Hypothesis (Andrew Lo, JPM, 2005)**

● ● ● | Evolution of the economic thought



Thank you for your attention!

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