Uncertainty, Risk and Brain: Toward a neurofinance

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Agenda

1) Methodological background

2) How brain grasps uncertainty: Brain working processes

3) The neural components of Risk construction: expectations, perceptions, reactions

4) A mental categorization of uncertainty

5) Back to finance analysis: insights and questions

1) Methodological Background

Consistency and relevance

- **The main property of** the various models derived from Economics and Finance Theories are to be **consistent,** but what about their economic **relevance** ?

  -The two acceptance of "relevance":

  → **The Macro** relevance (statistically predictive),the **Micro** relevance (behaviorally predictive)

- **From Micro to behavioral relevance**: The models are relevant if their propositions do not contradict human behaviors observed in **decision-making situations**. In case of contradictions, alternative models are induced from the observed behavior, by reference to economics or finance models (behavioral finance models):

➢ **Risk estimate** : overestimating, underestimating (Daniel, Hirschleifer, 1998…)

➢ **Risk reaction** : over-reactivity, under reactivity (de Bondt, Thaler, 1985, 1987…)

➢ **Risk decision and /or indecision**: aversion to ambiguity (Fox, Weber, 1998)

But what about the foundations of their behavior relevance?

- **From behavioral to neural Relevance**:

The behavioral models are behaviorally relevant if their behavioral assumptions derived from the observed behaviors can be explained by the human brain working in risky decision -making situations.

Problem:

→ How to rely **observed behaviors** in risky decision-making situations to corresponded **brain working processes?**

- **3 steps**

-1 - From behaviors observed in **real situ**ations to behaviors in **experimental situations** (experimental protocols, samples and interpretations) Experimental economics

-2 - From behavioral observed in **experimental situations** to **Neural processes and Brain machinery functioning** through technical devices,(neural tests, neural Imaging, chemical measurements…)

Neurosciences

-3 - From **neural processes** and Brain machinery understanding to **economics** and **finance** interpretations (Risk modeling, Bayesian, non Bayesian…)

Neuroeconomics

Neural investigation techniques

- Neural tests

- The Somatic markers. ex. Skin conductance responses (SCRs) as an anticipatorily marker of emotions (Bechara, Damasio, 2005)

- Neurophysiology

- Electro Encephalography (EEG), Mageto Encephalography (MEG)

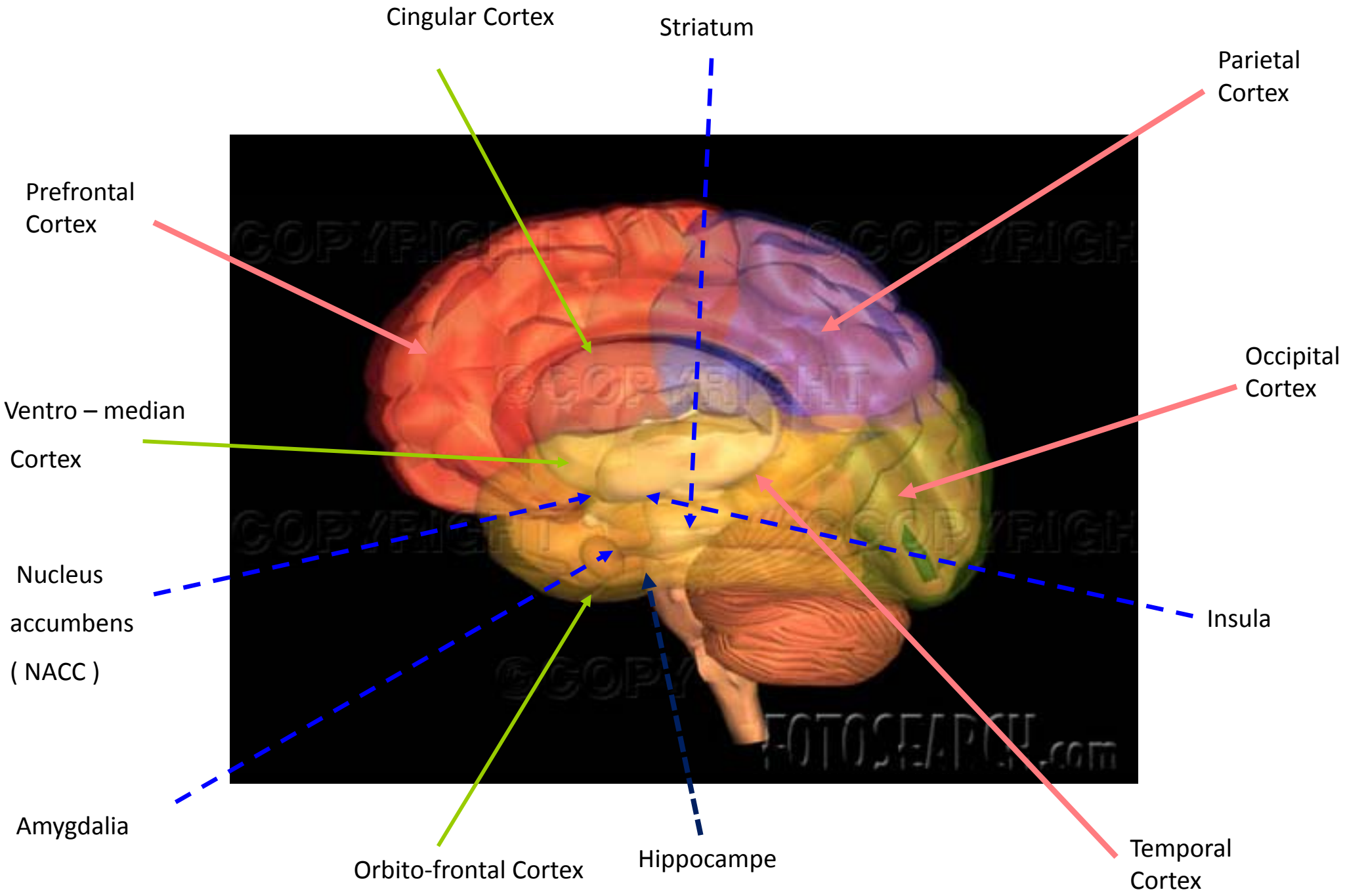
Measurements of electric current mediating neurons (Schultz, 1999, 2000)

- Brain imaging

- Positron Emission Tomography (PET), Fonctional Magnetic Imaging (fMRI)

Measurements of the blood oxygenation level dependence (Bold) signaling areas of brain activations.

Remark: Different spatial and temporal definitions from a technique to another, questions and discussions about the statistical measurement.



BRAIN BOARD

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2) How brain grasps uncertainty

Uncertainty is not a data but rather a question for the brain

- The mental treatment of uncertainty face to the decision-maker precedes his (her) choice: the "**Exploration-exploitation dilemma**" (Daw, alli., 2005, 2006; Yu, Cohen, Dayan, 2009)

- The two Processes:
  - **Exploration** (Information search)
  - **Exploitation** (Information valuation)

- The neural substrates of two different processes:
  - Exploratory activities →Frontopolar cortex +Intra parietal sulcus activation
  - Exploitative valued based activities →Prefrontal cortex +striatum

- Alternative or cumulative activations? **Switching** from **exploratory** to **exploitive** activities (and vice versa)

  Problems: Competition, conflict and /or Trade off →ACC activation

  Regulation, control and dysfunction via neurotransmitters (Dopamine and norepinephrine systems) (Mac Lure and alli, 2009).

3) The neural components of Risk construction

Mental expectations as a key mediator between anticipated feelings, present perceptions and reactions

Expected uncertainty versus **unexpected uncertainty** (Yu, Dayan, 2003,2005**;** Dayan, Yu, 2006)

1- Expected uncertainty (valuation)

- Neurotransmitter signaling →Acetylcholine
- Brain working process: From "top down" to "bottom up"(non model based)

2- Unexpected uncertainty (searching**)**

- Neurotransmitter signaling →Noreprineprine
- Brain working Process: From "bottom up" to "top down"(Based model)…

From unexpected to expected: The expectation construction (Neural Bayesianism)

From expected to unexpected : The **surprise**. Degrees of unexpectedness (Mars, 2008)

Problems:

- The vague boundaries between expected and unexpected (the "expected unexpected"?). Different Levels of unexpectation: Counter-expected, unexpected (Shackle, 1943)
- The regulation of the two signals (interruption, coordination?)≈Explor-exploit D (Mac Lure and alli, 2009)

4) A mental categorization of uncertainty

The **three** dimensions of expectations:

Emotional (returns), **Logic (semantics)** ,**Temporal (discounting)**

A) Emotional Returns

- **Anticipated gains**

  Neural predictors : Nucleus Accumbens (NACC) and ventral striatum activations (Knutson and alli, 2001; Khunen, Knutson, 2005)

  Anticipated gains and Risk seeking trough the "Reward system": The dopamine system (Schultz, 1998)

- **Anticipated losses**,

  Neural predictors: Anterior insula and amygdala activations (Khunen, Knutson,2005,

  Yacubian alli.,2009)

- Anticipated losses and risk averse through a possible "punishment system"(Khunen, Chiao, 2009; Khunen and alli., 2011)

Problems

- How to **dissociate** emotional impacts of **Returns** (Gains, losses) and **Risk**?: Passive versus, active, choice situations, non choice situations (Back and alli, 2009; VenKatraman and alli., 2011)
- **Experimented risk**: From anticipation to decision**: Switching** from risk seeking to risk adverse (or vice versa) which Threshold value?

B) Logic : subjective semantics

- The Mental interpretation of available information about uncertainty:

- 1-**Clear** interpretation: ex. A complete subjective probability distribution
- 2-**Unclear** interpretation**: Ambiguity**. Different kinds:
  - incomplete probability distribution (Ellsberg,1961….)
  - Several and contradictory probability distributions
  - Volatility dynamics

- **Discussion** about the neural signature: **One common sy**stem for uncertainty medium prefrontal cortex (Rustichini alli ,2005; Levy alli, 2010),**two different subsystems** for **Risk** and **Ambiguity** (Hsu aalli,2005; Huettel alli ,2006) prediction and decision-making (Bach and alli 2OO9;2010)

- From **information interpretation** to **behavioral attitude** : The case of ambiguity aversion (Fox Weber,2OO2;Rubalteti alli.,20010)
- Ambiguity aversion>Risk aversion

- Some consequences for **behavioral finance**

  -Ambiguous situations and **Procrastination**-→Passive and "wait and see" behaviors

  -Ambiguous situations and **Risk taking behavior** → moving to Risky stocks

A mental map for expectations

Semantics

Emotional	Clear	Ambiguous
Exp. Gains	Attractiveness	?
Exp. Losses	Aversion	?

Two different kinds of Aversion :

A1 - Aversion to losses

A2 - Aversion to ambiguity

Questions: Does A1 dominates A2 (or vice versa)?

Do 1 and A2 interact (in what direction)?

C) Temporal Discounting

Expectations are not static, but belong to a dynamic evolutionary process

- **Timing reward and brain areas activations** (Tanaka alli, 2004)

Expected immediate reward→ Cortex orbitofrontal and Striatum activations

Expected delayed reward→ Cortex prefrontal dorsolateral, cortex parietal

- **Different modalities and temporal profiles of activations** (Mac Lure alli 2004,2007)

EI Peak activation" just after the present " and rapid decreasing after.

ED Smooth evolution, even in spite of EI activation

if EI dominant →β (**hyperbolic** discount)

If ED dominant →δ (**exponential** discount)

- **E1 and E2 Dynamics coordination**

1- E1 **overvaluation** versus2 E2 **undervaluation** (Cherniasky Holroyd 2013)

2-Toward an intertemporal dynamics , non additive and non extensive, derived from Tsallis model trough chemical modulators (Dopamine, serotonine…) (Takabashi,2011)

.Cultural Differences:

Western (E1 dominant) versus Asian populations (E2dominant) (Takabashi,alli.2008; Kim alli,2012) → Economic consequences

5) Back to finance

Financial markets, Space/Time constraints and Brain working processes

- **Markets Constraints**
- Space : World connection ,de-Location, but “open space”
- Time: Continuous time, speed acceleration, short time reaction
- Information :Huge number of heterogeneous information, ambiguous content
- Automaticity and control : Computer models and search engines
- Potentiality and virtuality : Persons and operations

- **Brain working limitations and constraints**
- Repetition, acceleration and “reward circuit ”weakening→**”anti reward system**” and **addiction** (Koob Le Moal,2008; Schmidt2010)
- Limit time –profile of Brain working→ **risk seeking** and:or **risk averse** mistakes
- Brain aversion to ambiguity→ unexpected behaviors
- Task limitation **Max. 3 tasks simultaneous** (Koechlin Hyafil,2007)
- Disconnection between computational accounts and “mental accounts”(Thaler, 190,Dinetz,1999)→ **failure** and **uncontrolled switching** (Wu Knutson, 2O13)

financial Risky decision and neural predictors

- **Neural antecedents of financial decisions (**Preuschoff,Bossaert 2006, Knutson Bossaert ,2007)
- Increasing Ventral Striatum activation dominant →**Max. expected reward**
- Increasing Insula and orbito frontal activations dominant→ **Min. expected Risk**

- **Neural activations and subjective Risk assesment** (Wu alli,2012)
- Quantitative meta –analyze. Statistical Moments : Mean, Variance , skewness
- High mean, low variance, positive skewness →Ventral Striatum (ACC) over-activation
- High variance (high, or low mean, negative skewness) → Insula over-activation

- **Problem** : Neural response to conflicting statistical[2] moments