

Human, Artificial Intelligence and Financial Markets

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① Human Behavior in Markets

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③ Financial Market as an Environment

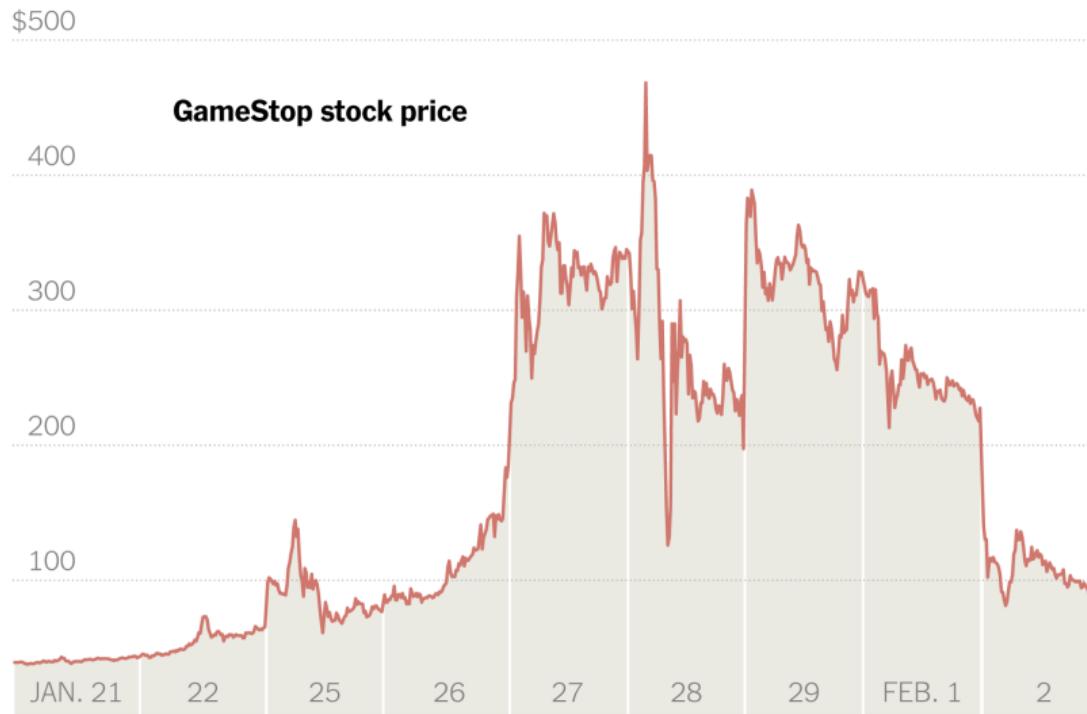
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More “audacious” behavior observed in financial markets



Source: The New York Times.

More “audacious” behavior observed in financial markets

- Degen: “a (retail) trader who yolos all their money on a degenerate investment in the hopes of it mooning.” - [Urban dictionary](#).
- Twitter: #GME, #AMC, #BTC, #LUNC, #APE, #TOTHEMOON🚀



Source: dogecoin.com

More “audacious” behavior observed in financial markets



Ryan Singh
@Superfly29tnt

...

Love this energy! DO NOT SELL #AMC GME NOK HOLD
THE LINE, NOT ONE STEP BACK.



10:27 AM · Jan 28, 2021 · Twitter for iPhone
© Twitter

Source: twitter.com

Why?

- In general, majority of the studies only see (care about) the end results: choices and consequences.
- Exploring ways to explain the choices and consequences.
 - ▶ Finance: mechanisms, regulations, etc.
 - ▶ Neoclassic economics: frameworks to rationalize these choices.
- But there is an obvious missing component: how do they converge to that point?

Intelligence and Learning

- Bottom line is: economy and markets evolve, so do agents.
- How market participants adapt to a rapidly evolving market merits more attention.
- I conjecture that understanding learning and intelligence is the key (not just their end choices).

Intelligence and Learning

A process by which experience results in a permanent shift in behavior or knowledge (Camerer, 2011; Eysenck, 2014).

Intelligence: the ability to **learn**, **understand**, make judgments or have opinions.

Reason about the environment and all agents including itself.

Autonomous actions or behavior.

Source: the Cambridge dictionary.

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Modeling Intelligence and Learning

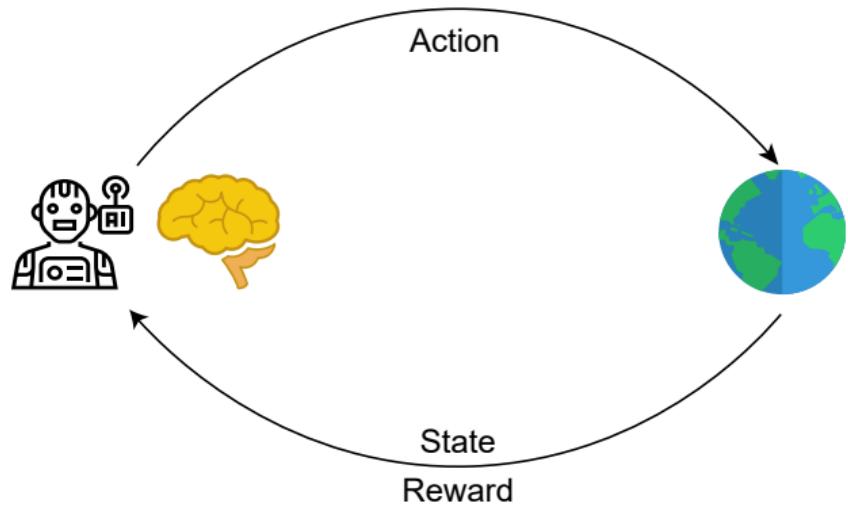


Figure 1: Agent-environment interaction¹. Adopted from Sutton and Barto (2018).

¹Source: Adobe image stock under Standard License; [Robot](#), [Brain](#), [Globe](#).

Modeling Intelligence and Learning

- Reinforcement learning (RL): a computational paradigm that models agents' learning and decision-making through interactions with an environment ([Sutton & Barto, 2018](#)).
 - There are other frameworks/models, e.g.,
 - ▶ Evolution, belief updating, experience-weighted attraction, direction and rule-based updating ([Camerer, 2011](#)).
 - ▶ Bayesian learning and active inference ([Friston et al., 2016](#)).

Why does (deep) reinforcement learning stand out?



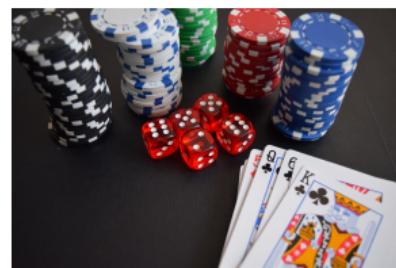
(a) Atari® games (Mnih et al., 2015)



(b) Game of Go (Silver et al., 2016)



(c) Starcraft II®. (Vinyals et al., 2019)



(d) Poker (Brown & Sandholm, 2019)

¹Source: (a) Atari (b) Game of Go (c) Starcraft II (d) Poker.

Quantitative Finance and Deep Reinforcement Learning

- Deep RL's ability to find completely new strategies and adapt to new environment attracts many practitioners in finance.
- Portfolio optimization, option pricing, risk hedging, market making, high frequency trading, etc.
- Academia: [Fischer \(2018\)](#), [Charpentier, Elie, and Remlinger \(2021\)](#), [Halperin \(2022\)](#).
- Industry: heavy presence of financial institutions in computer science journals and conferences, e.g., [JP Morgan AI Research](#), [Royal Bank of Canada](#).
- Does RL work in financial applications? So far (publicly) the answer is unknown ([Halperin, 2022](#)).

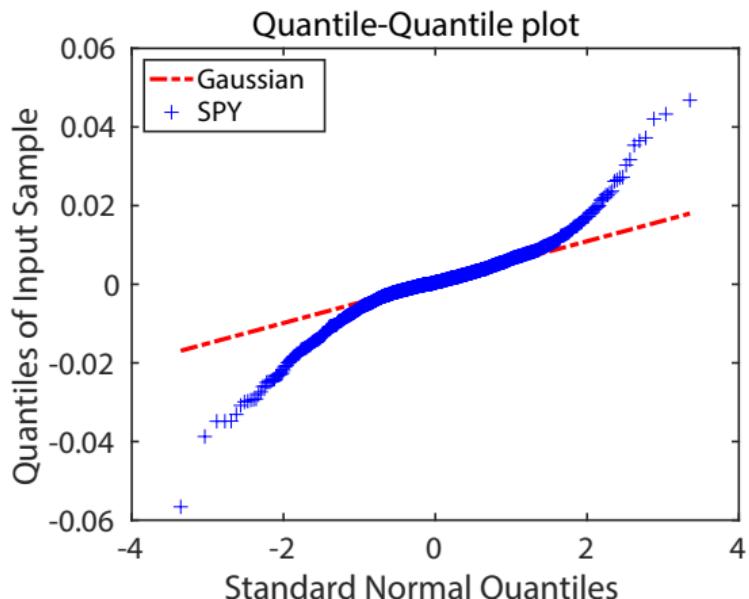
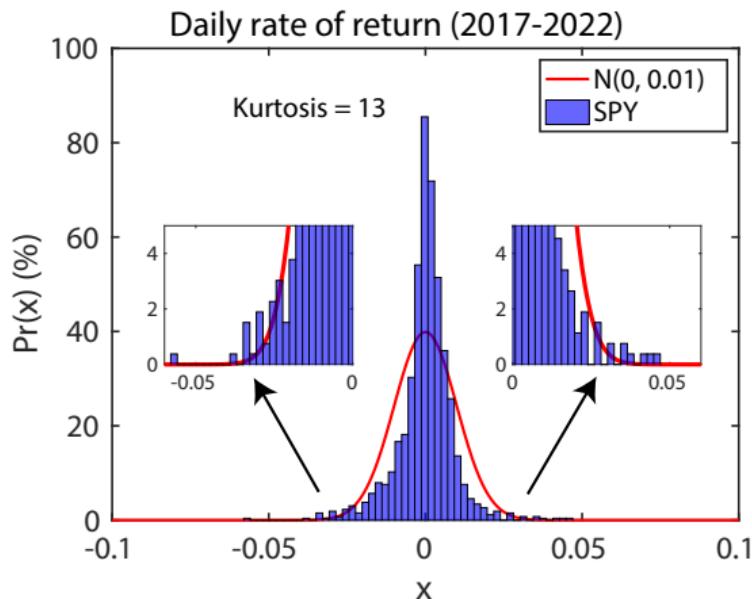
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A non-Gaussian World: Tail Risk (Taleb, 2020)



One research question: are humans and AI able to cope with this environment? why and why not?

Tail Risk: Should we care?

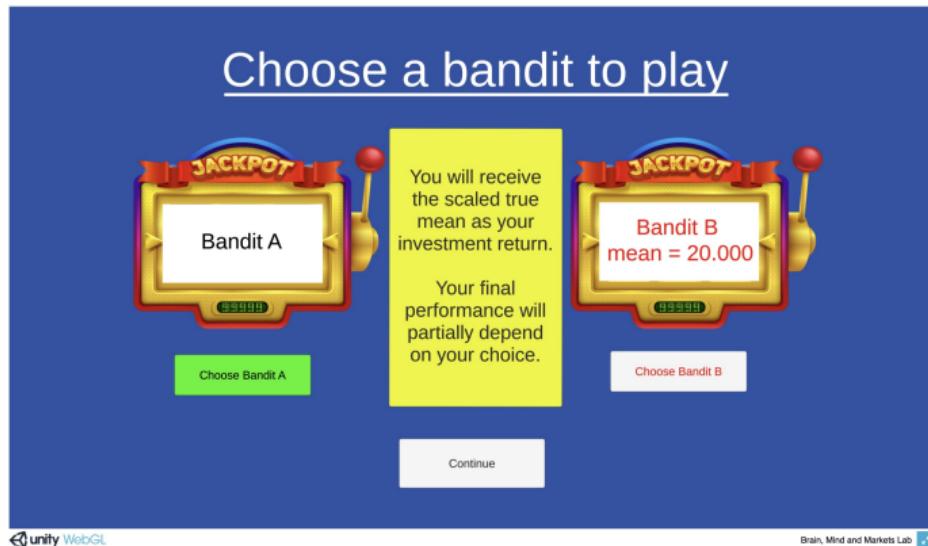
Some recent \geq **two-sigma** events:

- March 2020: global financial markets
- January 2021: GameStop
- March 2021: Greensill
- May 2022: Terra Luna
- July 2022: Three Arrow Capital
- November 2022: FTX/Alameda/BlockFi

The consequences endure, but more tailed events are coming...

Dissertation: Human, AI and Tail Risk

- Study 1 & 2: Can human and RL agents learn optimal actions efficiently on heavy-tailed rewards?
- Method: experiments using multi-armed bandit task with heavy-tailed rewards.
- Results: RL agents' learning are heavily affected by tail risk whereas humans show efficiency in learning optimal actions.



Dissertation: Human, AI and Tail Risk

- Study 3: what causes heavy-tailedness?
- Method: a paradigm comprises a single-widget economy, a continuous open-book market, and a group of trading agents with different intelligence levels.
- Results: Trading generates excessive kurtosis even when the underlying economy shifts follow a Gaussian law.

The screenshot displays a financial trading interface with three main sections: a summary bar at the top, a central trading area, and a detailed order book and trade history on the right.

Summary Bar:

CASH	SETTLED	AVAILABLE
\$995.74	\$990.49	
WIDGETS	11	12 <
PRIVATEWIDGETC	10	10

Central Trading Area:

Widgets Section:

- Buttons:** BUY (highlighted), SELL.
- Inputs:** UNITS (1), PRICE (\$0.01).
- Buttons:** PLACE BUY ORDER.

Order Book and Trade History:

WIDGETS < ORDER BOOK TRADE HISTORY

UNITS	PRICE	MINE	
1	\$6.90		1 \$5.94 ↘ 11:14:20.482
1	\$6.87		1 \$5.53 ↗ 11:14:19.818
1	\$6.72		1 \$4.57 ↘ 11:14:19.656
1	\$5.35	1 ×	1 \$5.13 ↗ 11:14:19.646
spread	\$0.10		1 \$4.93 ↘ 11:14:19.306
1	\$5.25	1 ×	1 \$5.31 ↘ 11:14:19.055
1	\$4.94		1 \$6.70 ↗ 11:14:18.718
1	\$3.87		1 \$5.32 ↗ 11:14:18.569
1	\$3.39		1 \$3.98 ↘ 11:14:18.296

PRIVATEWIDGETS ORDER BOOK TRADE HISTORY

UNITS	PRICE	MINE	WHO^	
1	\$5.03 ↘ 11:14:17.933			1 \$5.03 ↘ 11:14:17.933
1	\$5.13 ↗ 11:14:17.772			1 \$5.13 ↗ 11:14:17.772
1	\$5.57 ↗ 11:14:17.241			1 \$5.57 ↗ 11:14:17.241
1	\$4.81 ↗ 11:14:17.096			1 \$4.81 ↗ 11:14:17.096
1	\$4.43 ↘ 11:14:17.082			1 \$4.43 ↘ 11:14:17.082
1	\$4.74 ↘ 11:14:16.757			1 \$4.74 ↘ 11:14:16.757
1	\$8.20 ↘ 11:14:16.604			1 \$8.20 ↘ 11:14:16.604
1	\$5.53 ↘ 11:14:15.754			1 \$5.53 ↘ 11:14:15.754
1	\$6.76 ↗ 11:14:14.743			1 \$6.76 ↗ 11:14:14.743

Thank you!

Reference I

- Brown, N., & Sandholm, T. (2019). Superhuman ai for multiplayer poker. *Science*, 365(6456), 885–890.
- Camerer, C. F. (2011). *Behavioral game theory: Experiments in strategic interaction*. Princeton university press.
- Charpentier, A., Elie, R., & Remlinger, C. (2021). Reinforcement learning in economics and finance. *Computational Economics*, 1–38.
- Eysenck, M. (2014). *Fundamentals of psychology*. Psychology Press.
- Fischer, T. G. (2018). *Reinforcement learning in financial markets-a survey* (Tech. Rep.). FAU Discussion Papers in Economics.
- Friston, K., FitzGerald, T., Rigoli, F., Schwartenbeck, P., Pezzulo, G., et al. (2016). Active inference and learning. *Neuroscience & Biobehavioral Reviews*, 68, 862–879.
- Halperin, I. (2022). Reinforcement learning and stochastic optimization: A unified framework for sequential decisions. *Quantitative Finance*, 1–4.
- Mnih, V., Kavukcuoglu, K., Silver, D., Rusu, A. A., Veness, J., Bellemare, M. G., ... others (2015). Human-level control through deep reinforcement learning. *nature*, 518(7540), 529–533.
- Silver, D., Huang, A., Maddison, C. J., Guez, A., Sifre, L., Van Den Driessche, G., ... Hassabis, D. (2016). Mastering the game of go with deep neural networks and tree search. *nature*, 529(7587), 484–489.
- Sutton, R. S., & Barto, A. G. (2018). *Reinforcement learning: An introduction*. MIT press.

Reference II

- Taleb, N. N. (2020). *Statistical consequences of fat tails*. STEM Academic Press.
- Vinyals, O., Babuschkin, I., Czarnecki, W. M., Mathieu, M., Dudzik, A., Chung, J., ... others (2019). Grandmaster level in starcraft ii using multi-agent reinforcement learning. *Nature*, 575(7782), 350–354.