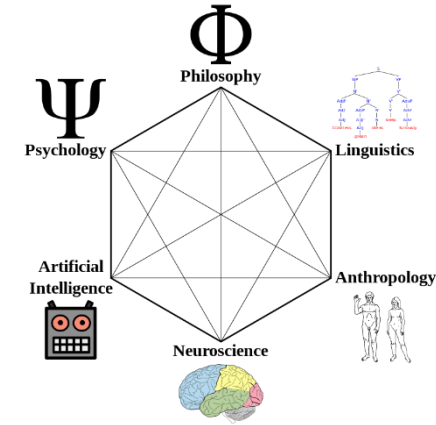# Confidence in value based decision-making



Maryam Hashemzadeh
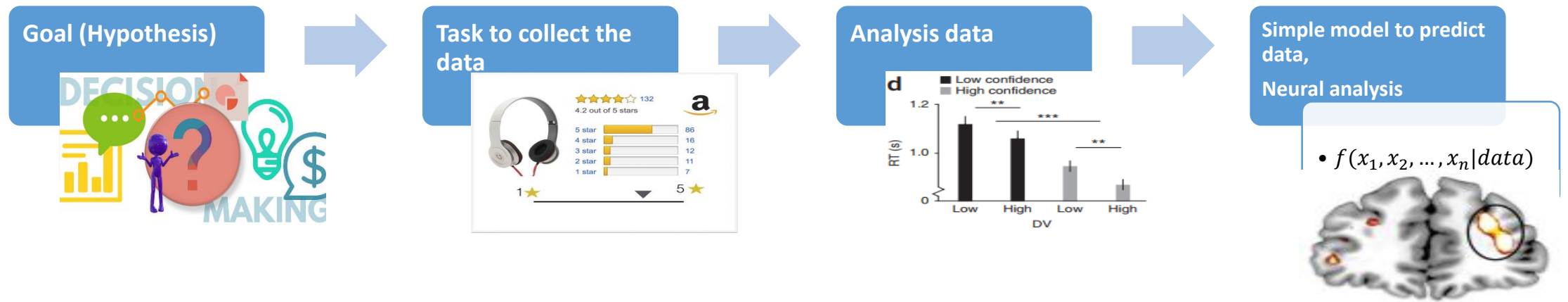
Winter 2019

# What is cognitive science?

- The study of the mind and what it does, including many scientific disciplines that touch on the subject.



- It explores through different aspects of mind to complete its puzzle.

# History

- In the 1800s, experimental psychology to search for specific human characteristics
- In the 1900s, they conducted projects with respect to that human mind is more than merely programmed responses.
- In the 1980s and 1990s, the complexity of the physical structure of the brain

# What is the approach in cognitive science?



**Goal (Hypothesis)** → **Task to collect the data** → **Analysis data** → **Simple model to predict data, Neural analysis**

- $f(x_1, x_2, \ldots, x_n | data)$

# The role of confidence in value-based decision making

✓ What is the confidence?

Confidence is a belief about the validity of our own thoughts, knowledge or performance and relies on a subjective feeling.

➢ How much do I like something? How sure am I?

✓ Confidence is often measured with retrospective judgment.
Do you see a vase or a face? Then the subject would immediately declare how confident he felt about that decision.

• How does confidence change decisions? (movie)

# Confidence in value-based choice

**Goal**: finding relationship between confidence with values, reaction times, and accuracy in the decision making.

**Task**:  fMRI task
Post scanning task

Benedetto De Martino  et al., NATURE HUMAN BEHAVIOUR, 2012
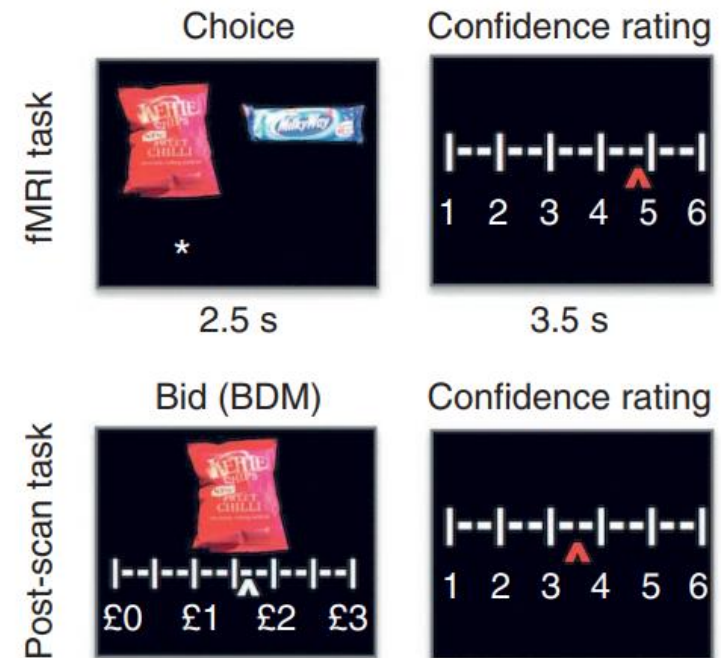
# Relation between confidence with value and accuracy

✓ To examine the effect of value and confidence on choice they compared five candidate logistic regression models:

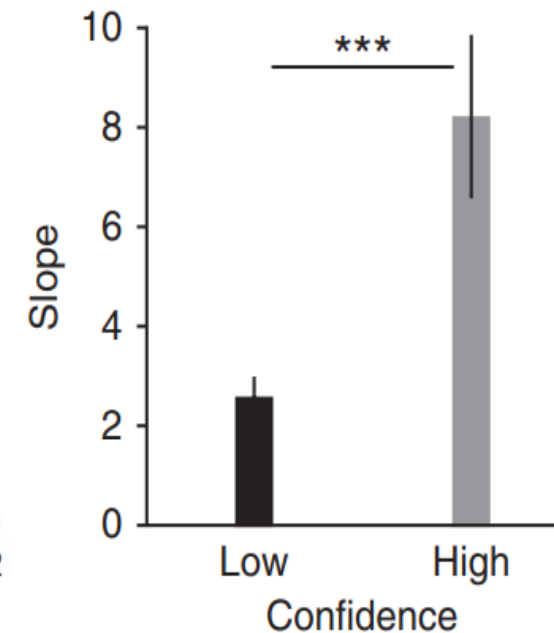$$P(c = R|X) = \frac{1}{1 + \exp(-\alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n)}$$
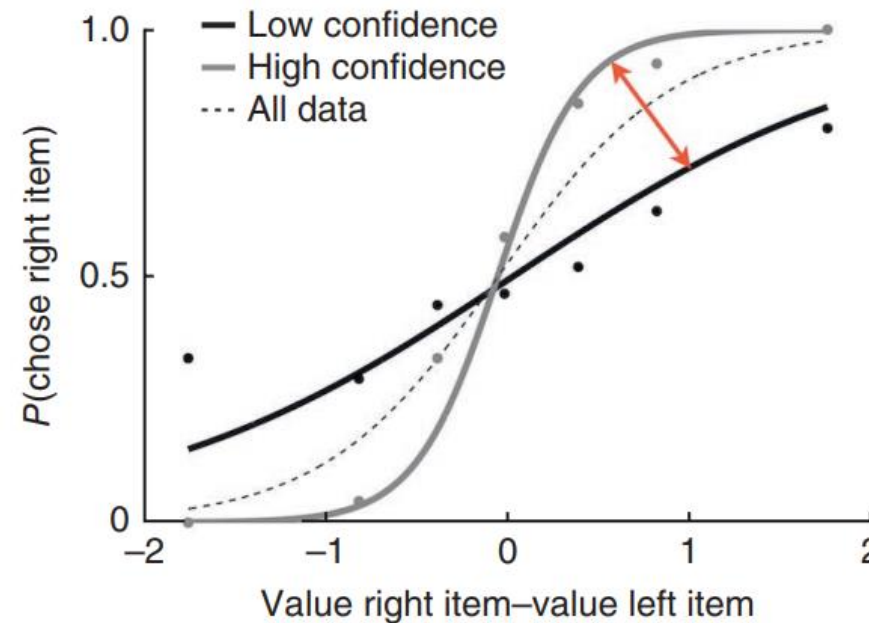
I. Separate low confidence choices from high confidence choices by median

II. DV= subtraction of the bid value of the right item from the bid value of the left item.

# Relation between confidence with value and accuracy

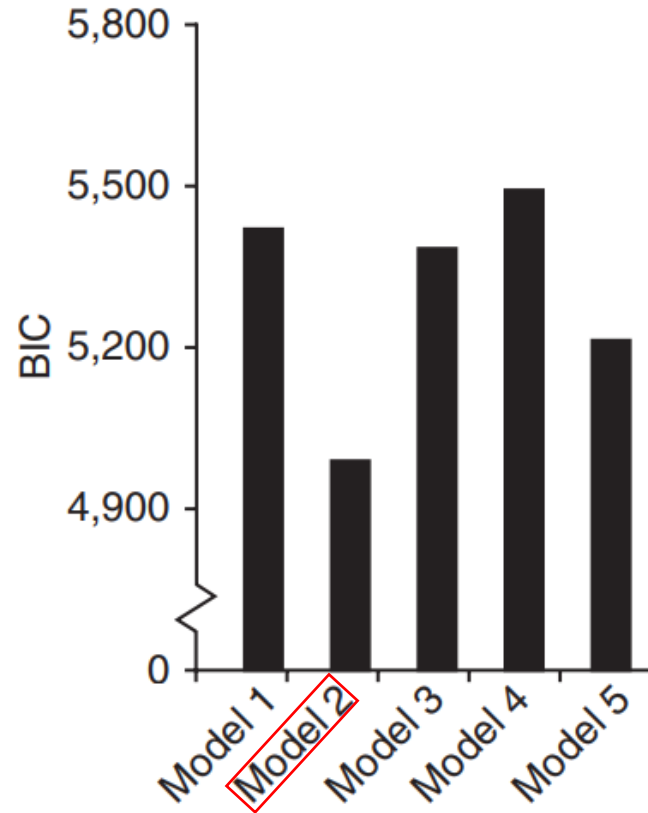**Model**:  $P(c = R|DV) = \dfrac{1}{1+\exp(\beta DV)}$

**Conclusion**:
When subjects had higher confidence choice accuracy increased .

# Logistic Regression Models



$$Model\ 1 : X = DV$$

$$Model\ 2 : X = DV \times conf_{choice}$$

$$Model\ 3 : X = DV \times \overline{conf}_{bid\ confidence}$$

$$Model\ 4 : X = [DV_{low},\ DV_{mixed},\ DV_{high}]$$

$$Model\ 5 : X = [DV_{low} \times conf_{choice},\ DV_{mixed} \times conf_{choice},\ DV_{high} \times conf_{choice}]$$

**Conclusion**: This analysis confirms that a critical modulator of choice accuracy is a second-order confidence arising in the context of the comparison process (model 2) as opposed to first-order confidence in the item values (models 3–5)

# Relation between confidence with reaction time and values

**Conclusion**:
The RT is higher when confidence is low in general and even is more higher when DV is low between the items
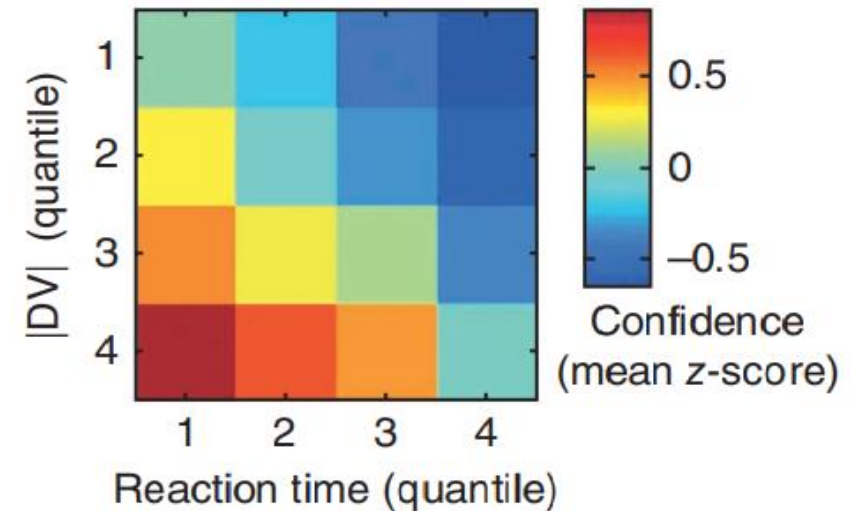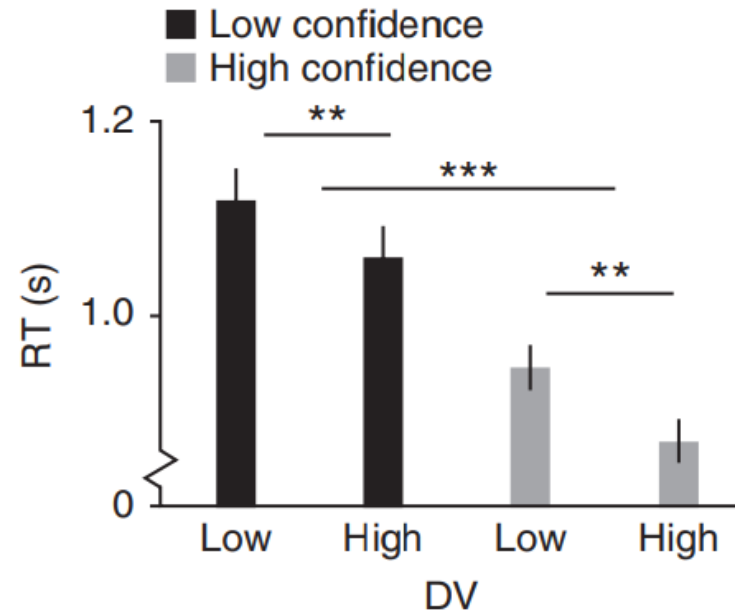
# Explicit representation of confidence informs future value-based decisions

**Goal**: How explicit (and well-tuned) representation of confidence in a recent choice can guide decision maker's choice when faced with the same (or a similar) decision again?

**Task**:
experiment 1: the same as before
experiment 2: to investigate more the relationship between factors – each pair was repeated three times.
✓ participants' eye movements were monitored.



Tomas Folke et al., NATURE HUMAN BEHAVIOUR, 2016
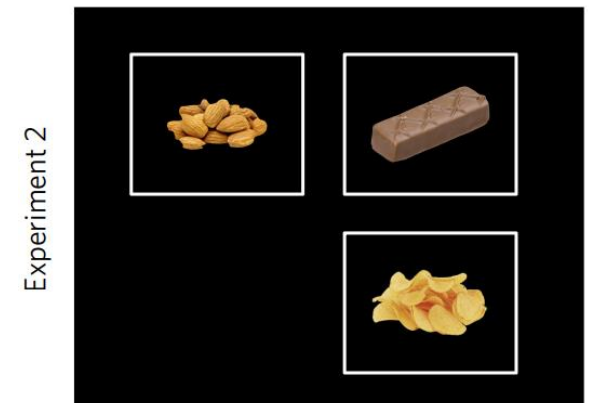
# Factors

- ✓ DV: subtraction of the bid value of the right item from the bid value of the left item

- ✓ RT: reaction time

- ✓ SV: summation of bid values at each step

- ✓ Confidence: choice confidence

- ✓ DDT (difference in dwell time): the total amount of time participants spent looking at each item

- ✓ GSF (gaze-shift frequency): how frequently gaze shifted back and forth among the options presented on the screen
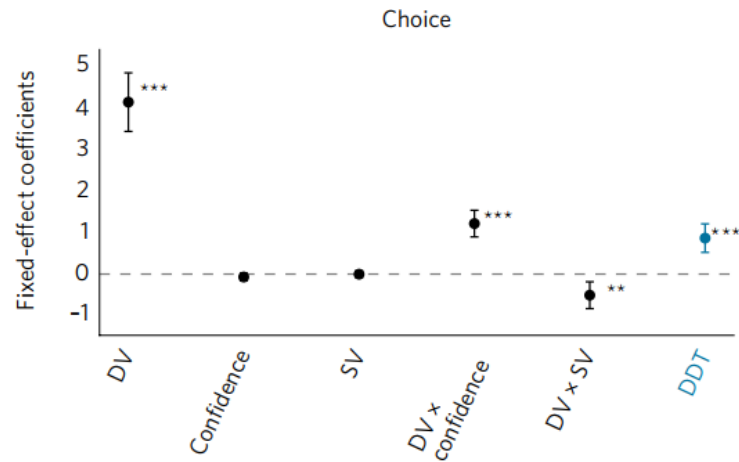
# Choice Model comparison (BIC)

- Hierarchical logistic regression models to examine the effects of value, confidence, and eye movements on choice.

$$P(c = R|X) = \frac{1}{1 + \exp(-\alpha + \beta_1 DV + \beta_2 Confidence + \beta_3 SV + \beta_4 DDT + \beta_5 DV \times Confidence)}$$
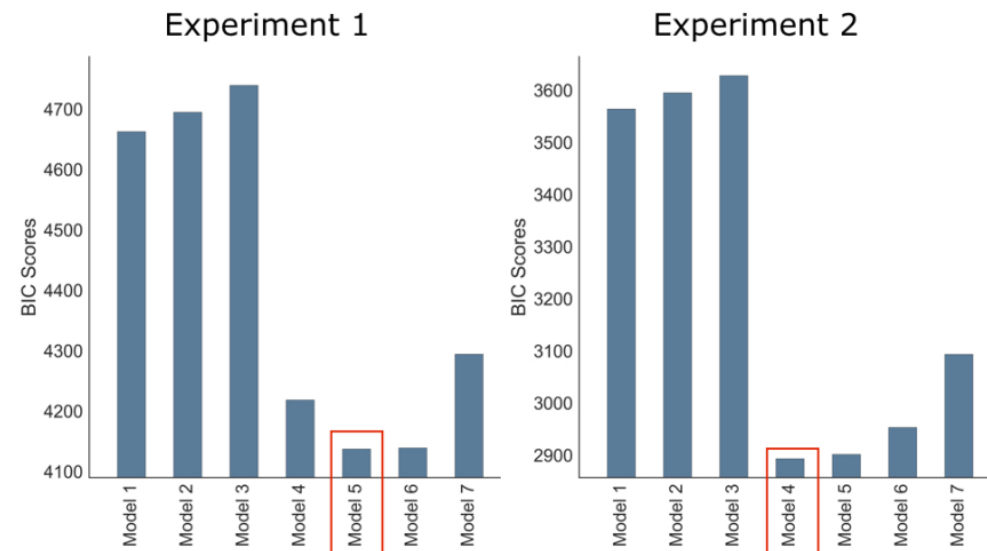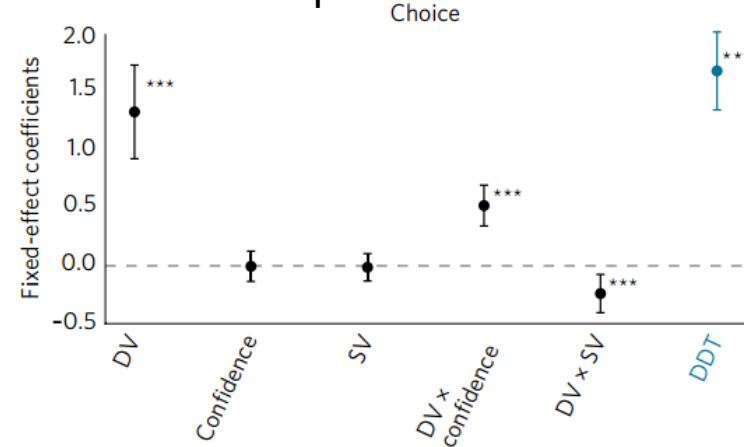
# Factors contribute to Choice model
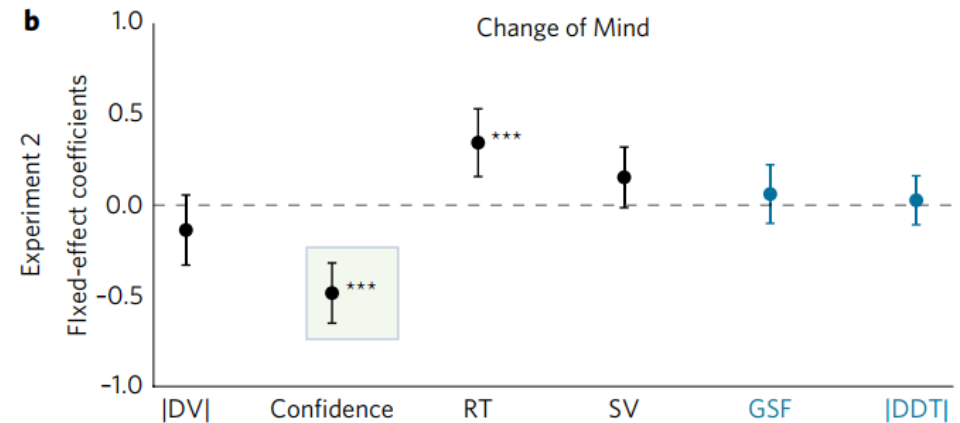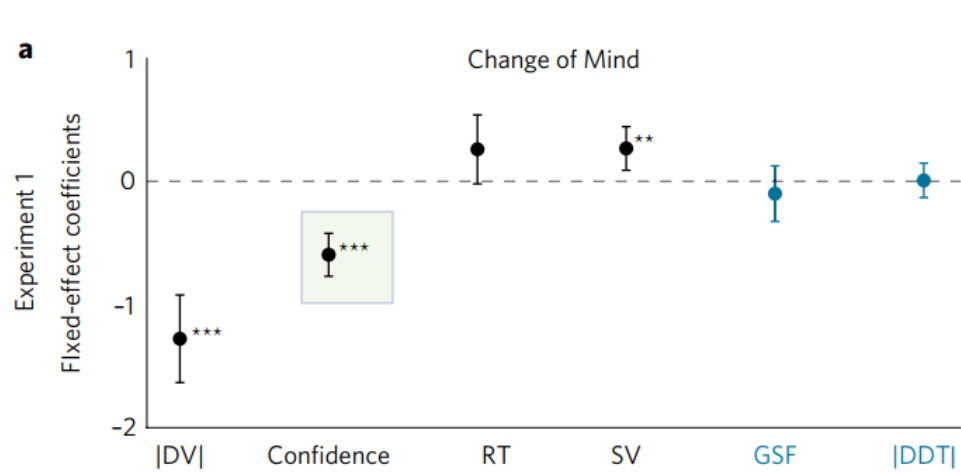
Experiment 1



Experiment 2



**Conclusion**:
DDT was a robust predictor of choice.

$$P(c = R|X) = \frac{1}{1 + \exp(-\alpha + \beta_1 DV + \beta_2 Confidence + \beta_3 SV + \beta_4 DDT + \beta_5 DV \times Confidence + \beta_6 DV \times SV)}$$

# Factors contribute to Change of mind

- Change of mind= choosing the other items



**Conclusion:**
✓ GSF is insufficient to trigger a future change of mind.
✓ An explicit representation of uncertainty may reverse their initial decision when the same (or a similar) choice is presented again.

# Link between confidence and choice transitivity

- How does "choice consistency" have correlate with confidence?

✓ Transitive ranking: if A>B and B>C then A>C.

✓ Failures of transitivity (transitivity violations, TV) are commonly observed in human choices.

✓ Minimum Violations Ranking (MVR) algorithm is used to minimize the number of inconsistencies in the ranking of the items for each participant's choices.
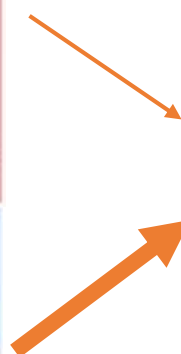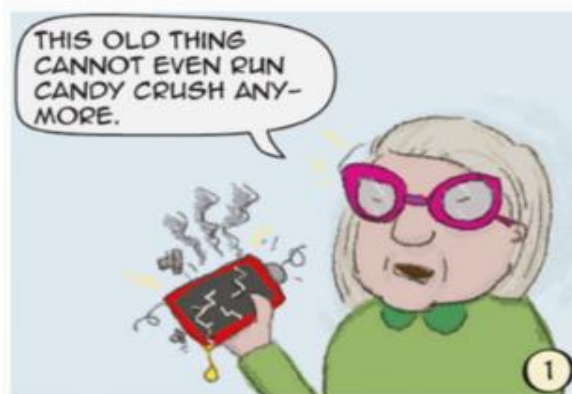
**Conclusion**:
The average value of TVs in high confidence trials is 16% and in low confidence trials is 84%.
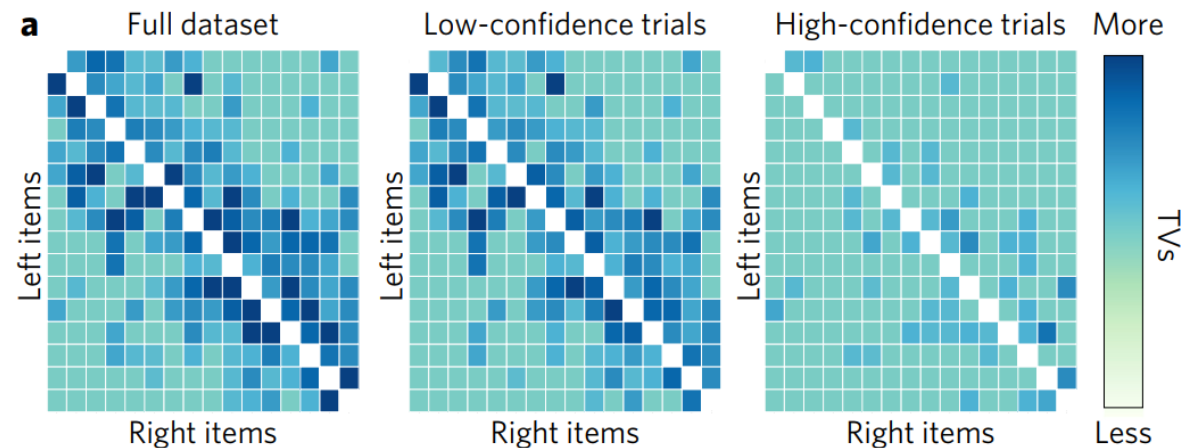
# Granny Smith and her two grandchildren Max and Moritz!

Bahador Bahrami, World Economic Forum, 2017

# Social Information Is Integrated into Value and Confidence Judgments According to its Reliability

**Goal**: Whether the human brain integrates social information according to its reliability and how this in turn affects valuation and confidence judgments.

**Task**:
Pre-scan task: liking rate, confidence of rating with descriptions.
fMRI task: Amazon rating.



Benedetto De Martino et al., Journal of Neuroscience, 2017

# Effect of social rating

**Conclusion**:
- ✓ Participants systematically updated their initial liking ratings in the direction of the group consensus.
- ✓ the magnitude of movement toward the group ratings was modulated by the level of confidence in their first rating.
- ✓ When the initial confidence was low, participants were more strongly influenced by the group consensus



**Predicting R2 - R1**
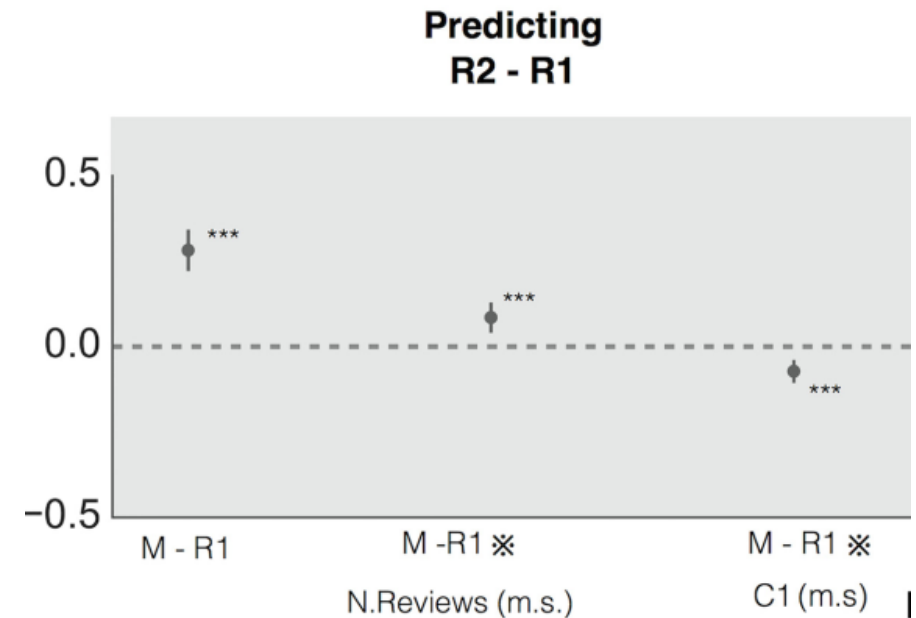
# Confidence modulates exploration and exploitation in value-based learning

**Goal**:
- ✓ Finding a link between people's belief confidence and decision confidence.
- ✓ How subjects use belief confidence for exploitation-exploration trade-off.

- Belief confidence: the uncertainty that subjects get over observations

- Decision confidence: the uncertainty that subjects have at the final step of the decision making
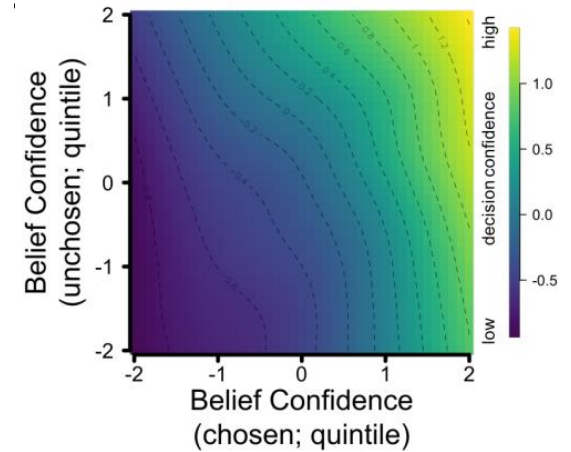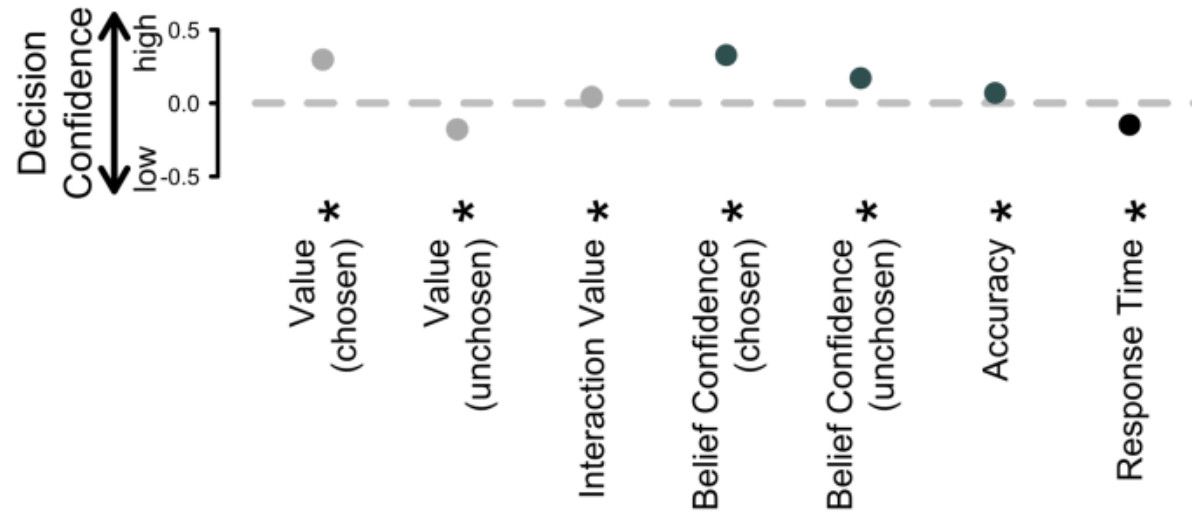


Annika Boldt et al., Journal of PLOSOne, 2017
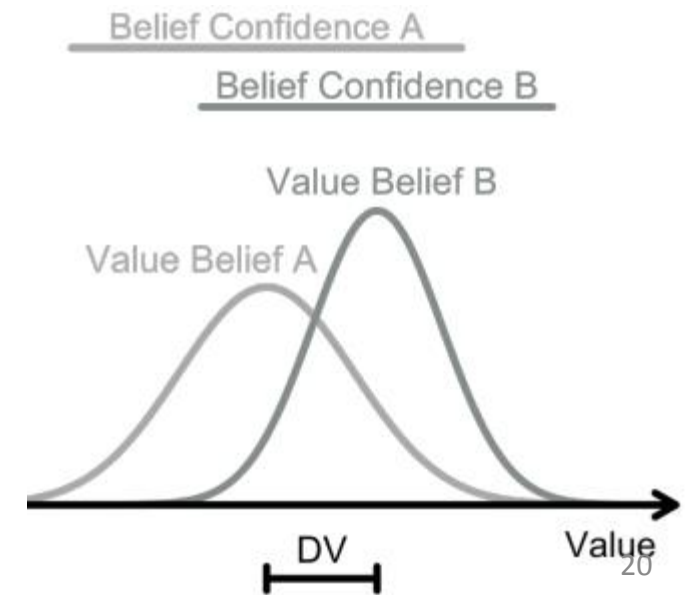
# Task

- ✓ Two lotteries (two-armed bandits)
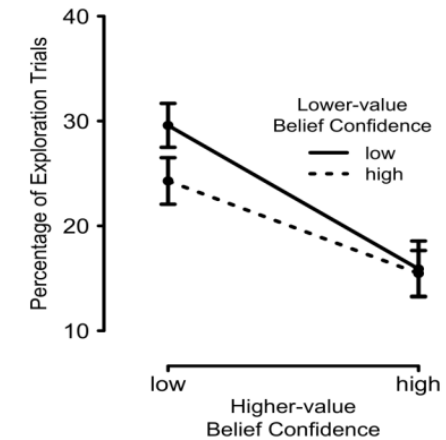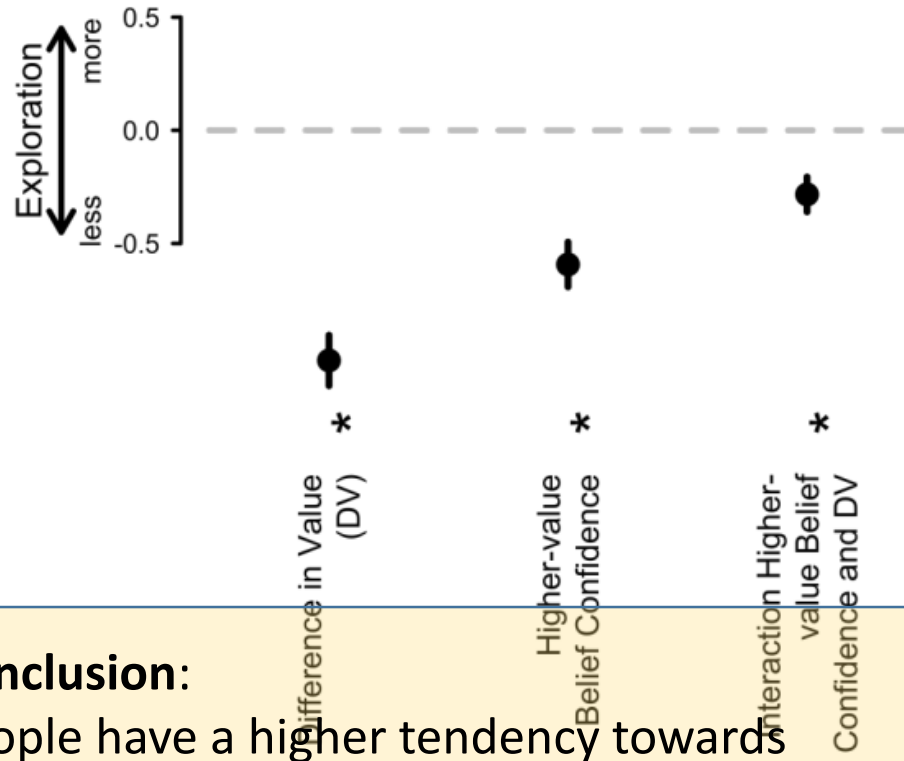- ✓ Rating trials, choosing trails
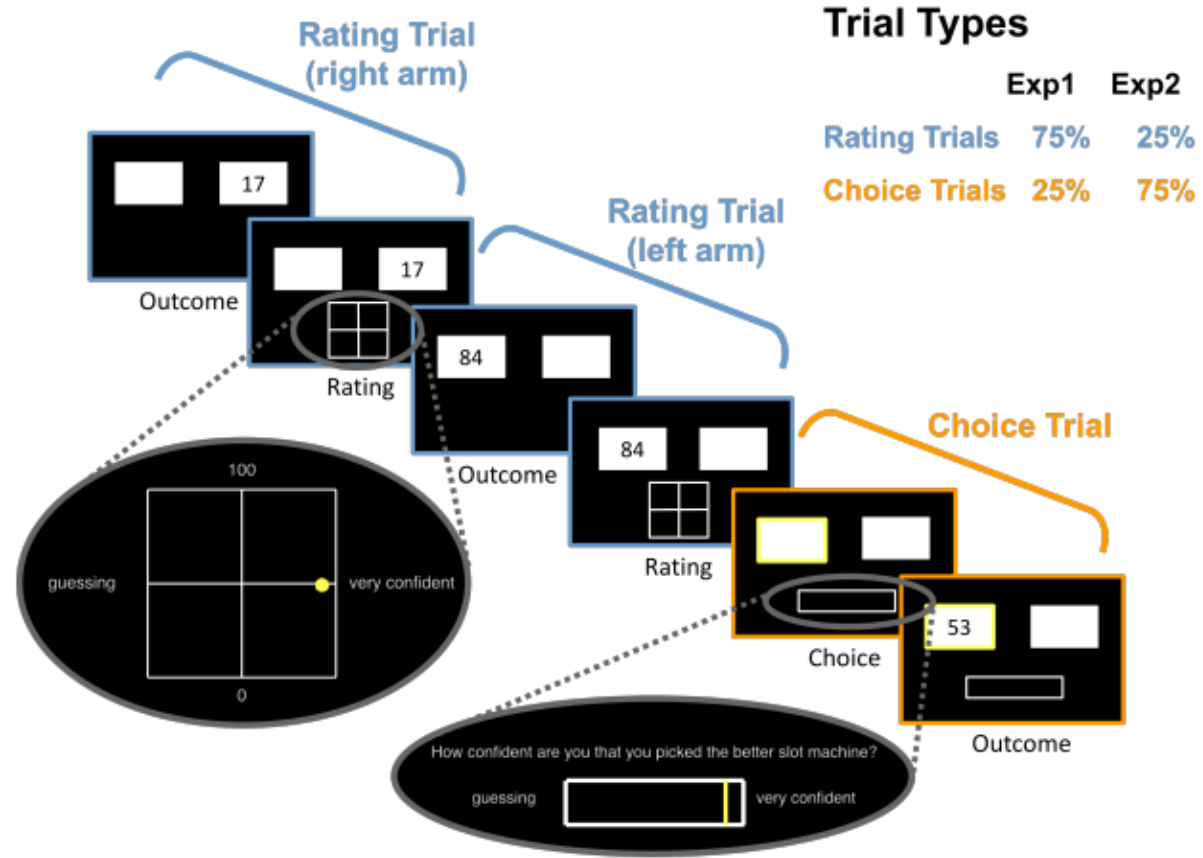
# Belief Confidence and Decision Confidence



**Conclusion**:
The level of certainty in the value we assigned to something can increase our decision confidence!
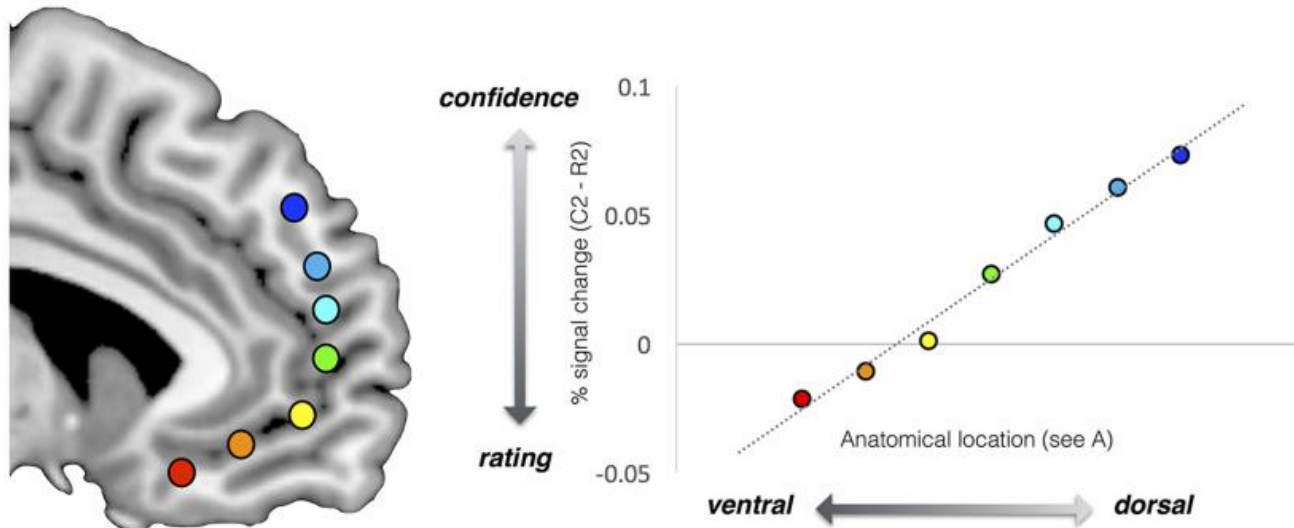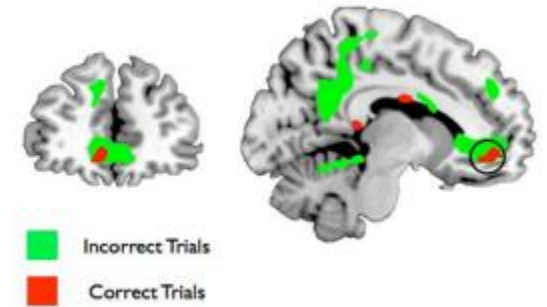
# Exploration and belief confidence



**Conclusion**:
People have a higher tendency towards exploration when their confidence in their value representations was low.

# How brain encodes confidence and value-based decision making

- *Effect of correct/incorrect choice signal in* ventromedial prefrontal cortex (*vmPFC)*



Incorrect Trials
Correct Trials

# Idea

- A combination of attention and confidence in a learning task:

- If confidence helpful to get more rewards

- If the presence/absence of rewards modifies the way people judge their confidence?

- (What is role of rewards on metacognition? How is metacognition effected by rewards? )

# References

- [1] De Martino, Benedetto, et al. "Confidence in value-based choice." *Nature neuroscience* 16.1 (2013).

- [2] Folke, Tomas, et al. "Explicit representation of confidence informs future value-based decisions." *Nature Human Behaviour* 1.1 (2017).

- [3] De Martino, Benedetto, et al. "Social information is integrated into value and confidence judgments according to its reliability." *Journal of Neuroscience* 37.25 (2017).

- [4] Boldt, Annika, et al. "Confidence modulates exploration and exploitation in value-based learning." *bioRxiv* (2017).

- [5] Fleming, Stephen, et al. "How to measure metacognition." *Frontiers in human neuroscience* 8 (2014): 443.

- [6] Grimaldi, Piercesare, et al. "There are things that we know that we know, and there are things that we do not know we do not know: Confidence in decision-making." *Neuroscience & Biobehavioral Reviews* 55 (2015).