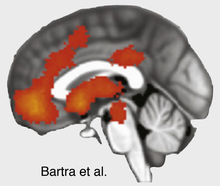
Neural Subjective Value Representations across Age and Discount Factors: Time Delay, Physical Effort, and Probability Discounting

Kendra Seaman [1], Nickolas Brooks [1], Teresa Karrer [1,2], Linh Dang [3], Ming Hsu [4], David H Zald [3], Gregory R Samanez-Larkin [1]

[1] Yale University, [2] TU Dresden, [3] Vanderbilt University, [4] University of California Berkeley

Background

- Real world decisions involve integrating rewards with other discounting factors such as **time delays, probability,** or **physical effort.**
  - The discounting of rewards by a range of factors generates a *subjective value (SV)* - a common currency - used to make decisions.
- A recent meta-analysis[1] supports the common currency hypothesis, showing that subjective values across tasks are represented in:
  - medial prefrontal cortex (mPFC)
  - posterior parietal cortex (PCC)
  - ventral striatum (vStr).
- These meta-analytic approaches focused on healthy young adults.
- Using tasks that integrate monetary rewards with either **time delays, probability,** or **physical effort,** we examined:
  - correlations between preferences across tasks
  - overlap of neural SV representations across tasks
  - age differences in preferences and neural SV representations.



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Method

Participants

75 healthy participants completed the study at Vanderbilt University
Mean Age (SD) = 49.71 (17.92), Age Range = 22 – 83, 44 Female, 33 Male

Procedures

- **Effort**: choices between a smaller reward with a lower level of physical effort and a larger reward with a higher level of physical effort.
- **Probability**: choices between a smaller reward with a higher probability and a larger reward with a lower probability.
- **Time**: choices between a smaller reward with a shorter time delay and a larger reward with a longer time delay.

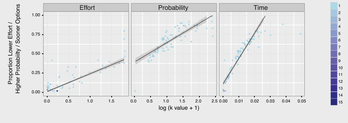
Computational Modeling

Subjective values were modeled using a hyperbolic discount function with Softmax action selection:

$$SV = R\left(\frac{1}{1+kC}\right)$$

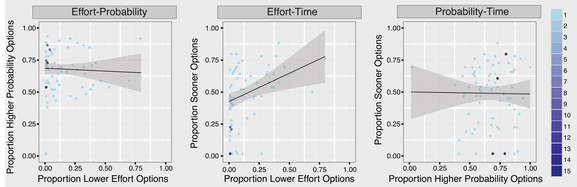
For each task, *C* represents either:
- **Effort:** Proportion of maximum ability
- **Probability:** Odds against winning (1-P(win)/P(win))
- **Time:** Time delay in days

There was a strong correlation between decision preference and discount rate.



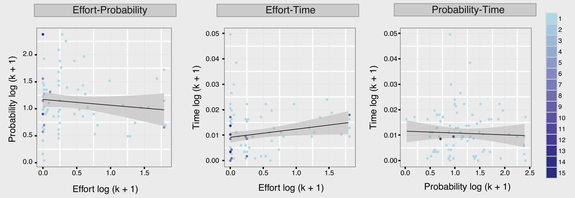
Decision Preferences (%choice)

Correlations between proportion of lower effort / higher probability / sooner options selected across tasks

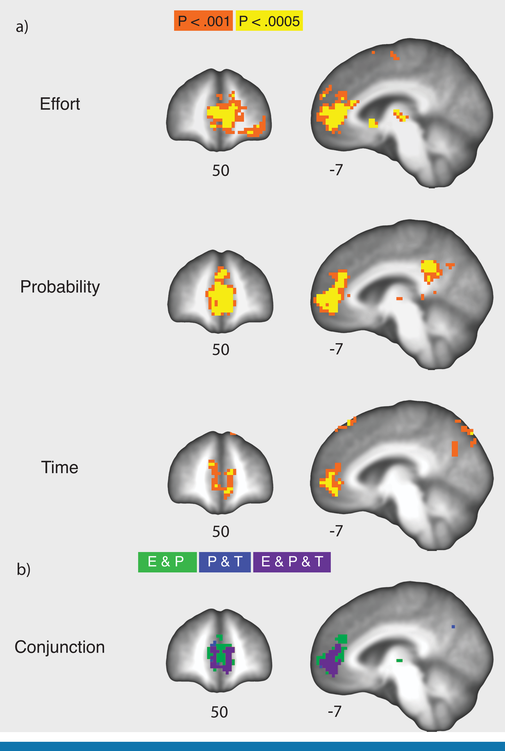


Discount Rates (k)

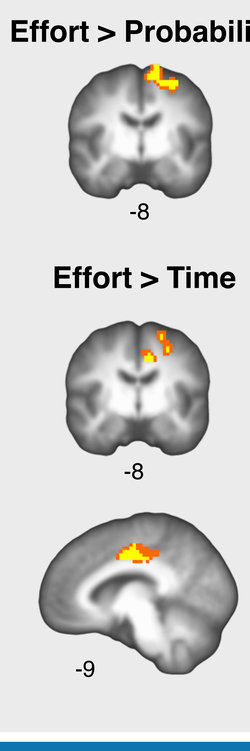
Correlations between discount rates (k) across tasks estimated using a hyperbolic discounting model



Subjective Value Representation



Differences in Representation



Conclusions

- No consistency in behavior across discount factors.
  - For example, someone can be very tolerant of delays, but intolerant to risk.
- Common representation of SV in the medial prefrontal cortex (mPFC).
  - Regardless of discount factor, the mPFC supports SV representation.
- There were some differences in SV representation for effort.
  - Could be preparatory motor activity.
  - Floor effects in behavioral data; may not be capturing true discount rates for effort.
- No reliable effects of age on behavior.
- Small, unpredicted effect of age on subjective value representations of effort.

Future Directions

- Psychophysiological Interaction analysis with mPFC as seed region to examine networks supporting subjective value representation.
- Using multi-voxel pattern analysis to examine for subjective value representation through the brain.
- Using partial least squares to examine the relationship between subjective value representation and dopamine binding potential.

References

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4. Massar, S. A. A., Libedinsky, C., Weiyan, C., Huettel, S. A., & Chee, M. W. L. (2015). Separate and overlapping brain areas encode subjective value during delay and effort discounting. *NeuroImage*, 120:104–113.

Acknowledgments

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Correspondence should be addressed to: kendra.seaman@duke.edu