Temporal and Spatial Discounting are Distinct in Humans

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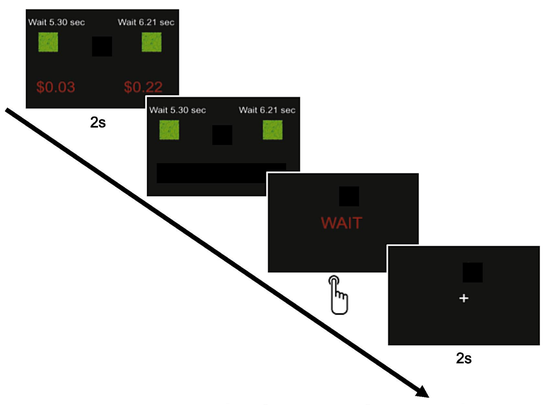
Introduction

- Physical effort: actual energetic cost of traveling to attain a certain reward
- Cognitive effort: cognitive load necessary to attain a reward [2][4][5]
- Temporal discounting can be solely evaluated as one dimension while effort/energetic discounting is multidimensional; traversing a spatial interval involves both a temporal component and a direct/energetic component [4][5]
- Can spatial discounting be disentangled from temporal discounting? [1][3][6]
- Using virtual reality, we removed energetic costs of physically traversing space, thereby isolating the time component of intertemporal/interspatial discounting

Experiment One

Behavioral Tasks



Temporal Discounting Task

- Keypress and hold to estimate temporal interval to reach desired reward

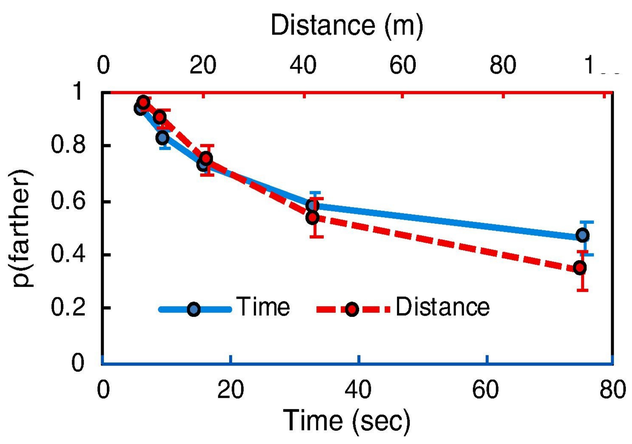
Spatial Discounting Task

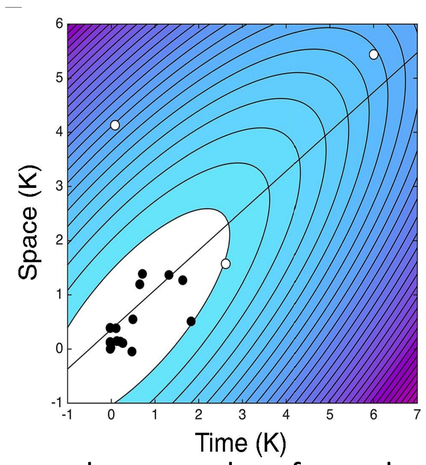
- Movement in the VR environment occurred at a constant speed (1.3 m/s)

$$V = \frac{A}{1 + Kt}$$

***fitting done using Maximum Likelihood estimation of single trial responses**

(V) Subjective reward value
(t) Delay
(K) Discounting constant: lower values indicate greater propensity to chose larger reward
(A) Reward value

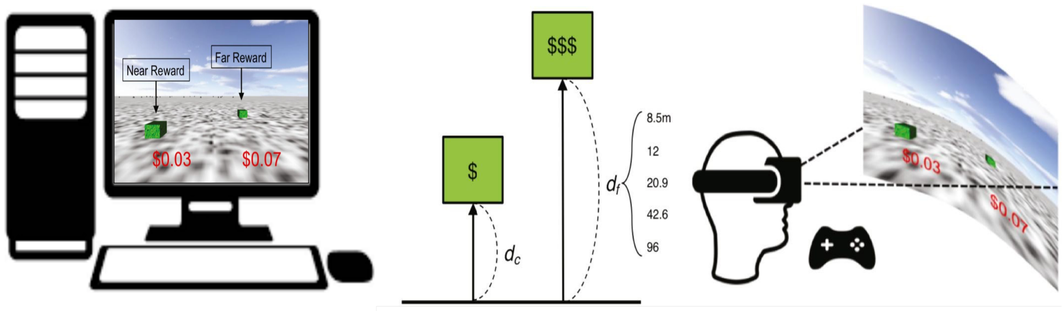




- Average proportion of choosing the farther reward across values for each of the five tested durations and distances. Subjects displayed a similar level of discounting across the two tasks

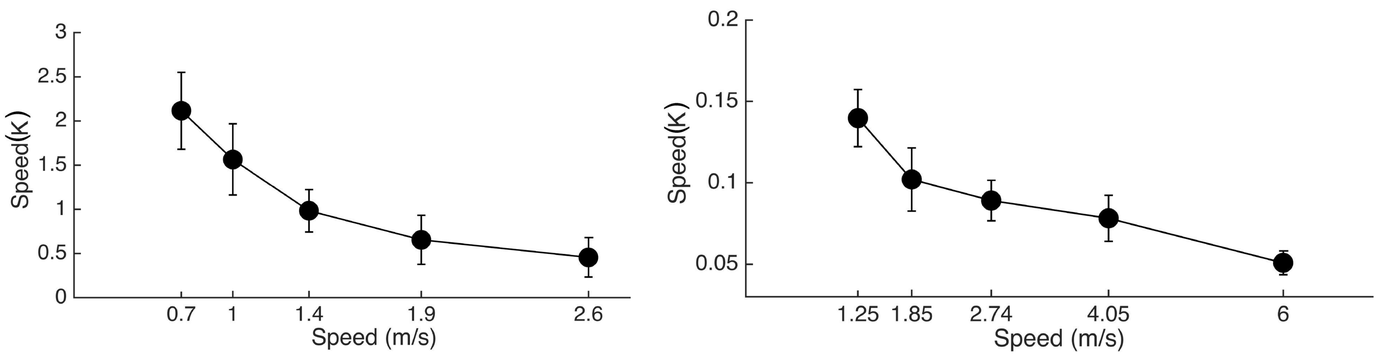
- No significant difference was observed between discounting values for temporal and spatial discounting tasks

- Values of K from hyperbolic discounting functions for temporal and spatial discounting tasks, also demonstrating a similar level of discounting that was correlated between subjects

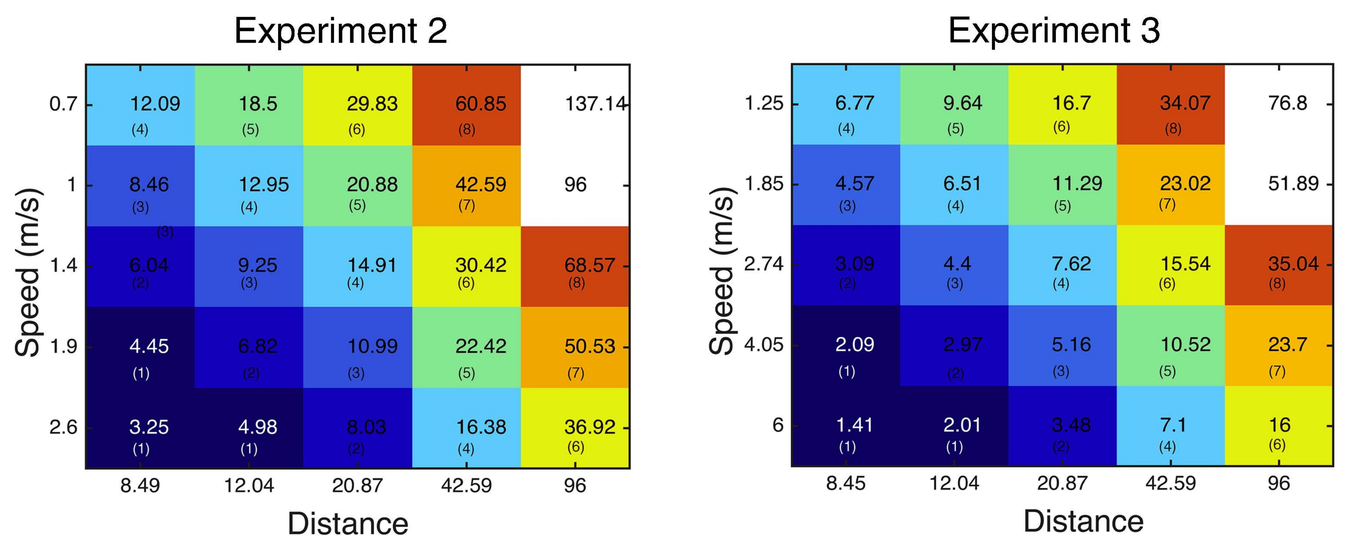


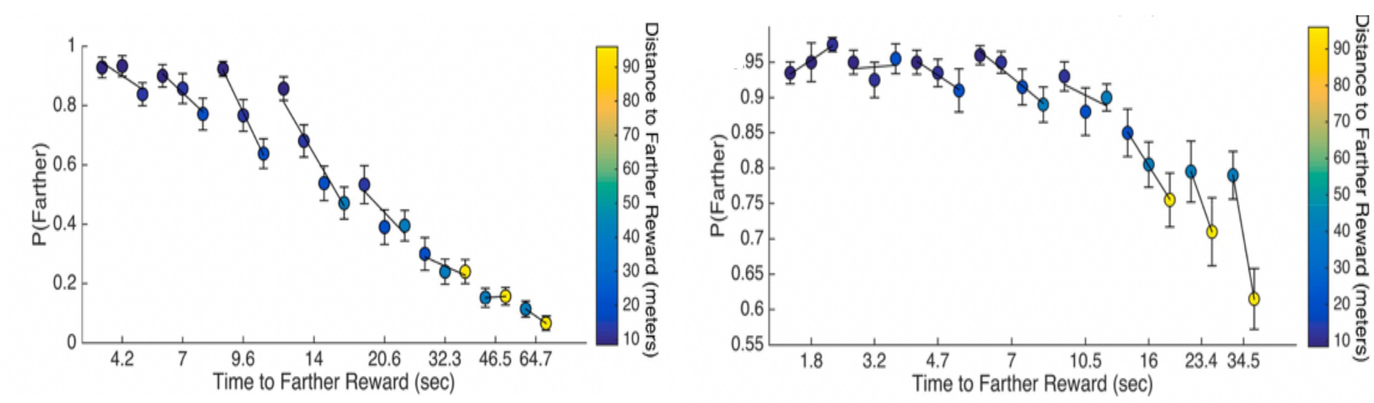
- **Experiment Two**: walking speeds were covaried between trials (log-spaced (0.7-2.6 m/s), values and distances remained the same at experiment 1
- **Experiment Three:** Walking speed covaried at five levels, faster than in Experiment 2 (1.25-6 m/s), larger reward was located at five different distances from the participant (8.49-96m) and values varied ($0.03-$5.50)

Experiment Two and Three



- Average proportion of picking the farther reward with K as a function of speed, collapsed across distance and value, for each of the speed values of Experiments 2 and 3, showing increased propensity for picking farther rewards with faster walking speeds

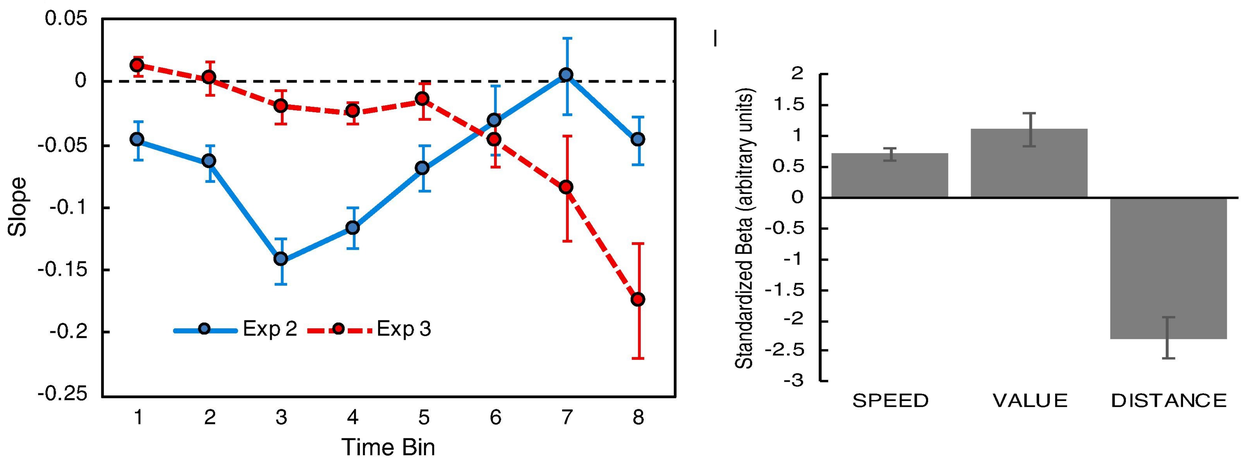




- Average proportion of trials on which participants chose the farther reward, collapsed across distance, each set of distances is presented within the binned time interval to reach that reward

- An effect of distance is also observed, but not for very short intervals- when the speed to reach a farther reward is very fast, and the distances are close, disparities in distance have little impact on discounting

Dissociations Between Time and Distance in Spatial Discounting



- **For Experiment Two** (slower speeds) subjects stopped dissociating between reward distances when the time to reach them was very long

- **For Experiment Three** (faster speeds) subjects dissociated between farther distances reachable in a shorter amount of time, but did not dissociate between distances when those rewards were very close

- These findings provide support for independent representations of time and space in delay discounting, supporting a multiplexing role for both dimensions in decision making

Results from this study have been published in Cognition

Robinson, E., Michaelis, K., Thompson, J. C., & Wiener, M. (2019). Temporal and spatial discounting are distinct in humans. *Cognition, 190,* 212-220. doi.org/10.1016/j.cognition.2019.04.030

References

[1] Eichenbaum, H. (2017). On the integration of space, time, and memory. *Neuron, 95*(5), 1007–1018. [2[Mitchell, S. H. (2017). Devaluation of outcomes due to their cost: Extending discounting models beyond delay. *Impulsivity* (pp. 145–161). Cham: Springer. [3] O'Connor, D. A., Meade, B., Carter, O., Rossiter, S., & Hester, R. (2013). Behavioral sensitivity to reward is reduced for far objects. *Psychological Science, 25*(1), 271–277. [4] Ostaszewski, P., Bąbel, P., & Swebodziński, B. (2013). Physical and cognitive effort dis- counting of hypothetical monetary rewards. *Japanese Psychological Research, 55*(4), 329–337. [5] Read, D., McDonald, R., & He, L. (2004). 5 Intertemporal Choice.[6] Stevens, J. R., Rosati, A. G., Ross, K. R., & Hauser, M. D. (2005). Will travel for food: Spatial discounting in two new world monkeys. *Current Biology, 15*(20), 1855–1860.