The Influence of Reward-Motivated Memories on Learning Across Development

Camille V. Phaneuf[1], Alexandra O. Cohen[1], Morgan M. Glover[1], Kristen N. Avallone[1], Xinxu Shen[1,3], Catherine A. Hartley[1,2]
[1]Psychology, New York University; [2]Neural Science, New York University; [3]Psychology, Temple University

background

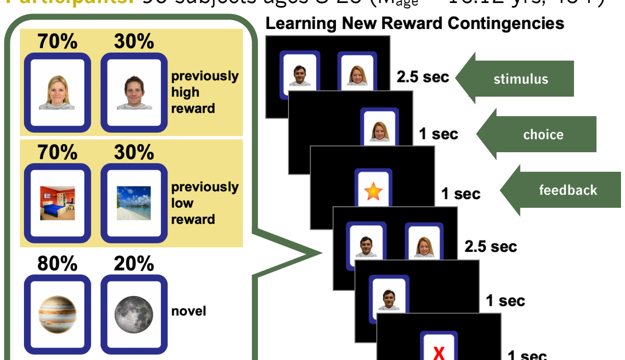
Cues associated with past rewarding experiences can harness attention and influence choices in new situations[1]; increased attention to previously reinforced stimuli might confer benefits for other goal-directed behaviors.

Heightened reward sensitivity may lead to a particularly robust influence of value-related memories on future behaviors during adolescence, relative to childhood and adulthood.

Aim: characterize age-related changes in how prior reward associations impact later learning.

methods

Participants: 90 subjects ages 8-25 (M_{age} = 16.12 yrs, 45 F)



Task design inspired by Decker et al. (2015)[2]

How can previously rewarded experiences influence new learning?

Value transfer to initial value estimates

Reward history may influence value estimates of choice options at outset of new learning. *Transfer mechanism supported by best-fitting computational model.*

Value transfer effects on learning rate

Reward history may influence how feedback is incorporated into choice option valuations.

Computational Models: variants of Q-learning algorithms, using softmax choice policy

$$Q_{t+1}(s,a) = Q_t(s,a) + \alpha\delta_t$$

- t decision time point
- s stimulus
- a selected action
- α learning rate
- $\delta_t = r_t - Q_t(s,a)$ prediction error
- r_t reward outcome

$$p(a|s) = \frac{exp(\beta Q(s,a))}{\sum_i(exp(\beta Q(s,a)))}$$

- β inverse temperature (specifies degree to which the magnitude of difference between choice option Q-values translates into deterministic decisions)
- *Sum* over possible actions [choose deck on left, choose deck on right]

ACKNOWLEDGEMENTS: This work is supported by a Klingenstein-Simons Fellowship Award in Neuroscience, Jacobs Foundation Research Fellowship, and NSF CAREER Award 1654393 to C.A.H.

results

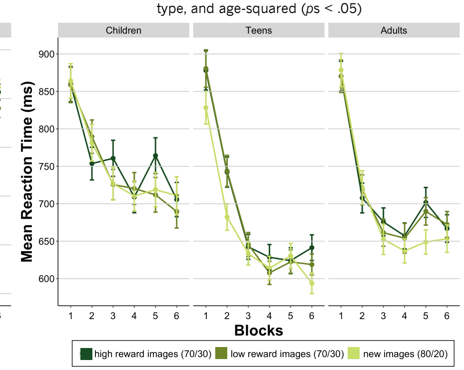
Learning: Accuracy

main effects of instance, stimulus type, and age on response accuracy; significant interaction between instance and age ($ps < .001$)

Response accuracy improves throughout the task and with age, is highest for new images, and is lowest for previously high reward images.

Learning: Reaction Time

main effects of instance and stimulus type on reaction time; significant interaction between instance, stimulus type, and age-squared ($ps < .05$)

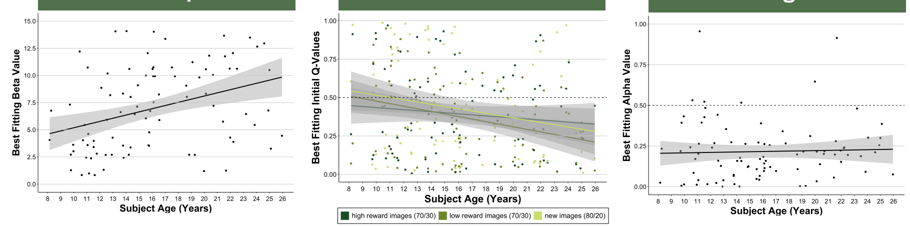


Particularly in adolescents, response time decreases throughout the task, is longest for previously high reward images, and is shortest for new images.

Parameter Estimates

for best-fitting model, across continuous age

Inverse Temperature | **Initial Value Estimates** | **Learning Rate**



Choice behavior becomes more deterministic with increasing age, suggesting that older individuals can better discriminate between reinforced stimuli in a probabilistic learning task. Initial value estimates of choice options decrease with age, suggesting that prior reward associations affect future goal-directed behavior less in older individuals.

Adults are more efficient learners in this task and may be better at adjusting their learning to the statistics of their environments[3,4]. Thus, they may rely less on value-transfer mechanisms as an aid for new learning, while children may leverage reward history as a strategy in their future, goal-directed behavior.

Future directions: investigate potential age-related differences in best-fitting computational model to explore how previously rewarded experiences influence early learning trajectories across development.

[1]Insel et al. (2019). Neurodevelopmental shifts in learned value transfer on cognitive control during adolescence. *Develop Cogn Neurosci.*
[2]Decker et al. (2015). Experiential reward learning outweighs instruction prior to adulthood. *Cogn Affect Behav Neurosci.*
[3]Master et al. (2020). Disentangling the systems contributing to changes in learning during adolescence. *Develop Cogn Neurosci.*
[4]Nussenbaum & Hartley (2019). Reinforcement learning across development. *Develop Cogn Neurosci.*