Lifespan developmental differences in the effects of opportunity cost on cognitive effort

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INTRODUCTION

Previous work suggests that lifespan developmental differences in cognitive control are due to maturational and ageing-related changes in PFC functioning [1, 2]. However, there are also alternative explanations: For example, it could be that children and older adults differ from younger adults in how they balance the effort of engaging in control against its potential benefits. Here, we assume that the degree of engagement in cognitive effort depends on the opportunity cost of time (average reward per unit time) [3]. If the average reward is high, participants should speed up responding whereas if it is low, they should respond more slowly. Developmental and ageing-related changes in opportunity cost assessments may lead to differences in the sensitivity to changes in reward rate.

METHODS

Flanker task

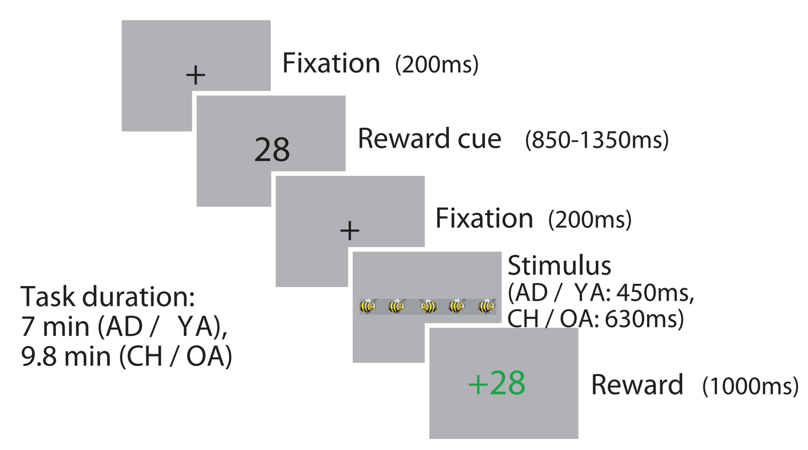


Figure 1A) Participants have to indicate whether the bee in the center of the display is flying to the left or the right. On compatible trials, the surrounding bees are flying in the same direction. On incompatible trials, they fly into the opposite direction. To account for slower RT in children and older adults, we adjusted stimulus display times.

Task switching task

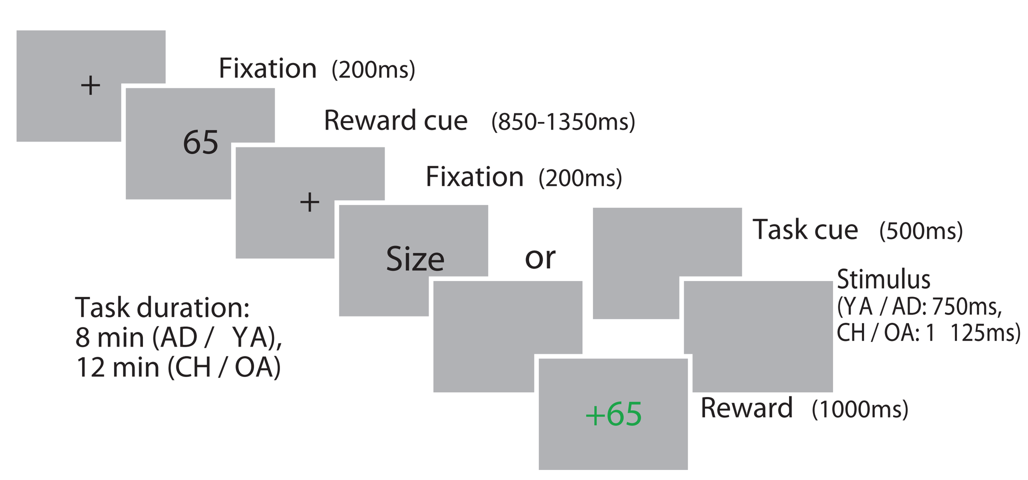


Figure 1B) In the task-switching paradigm, participants either indiviate whether the object was a fruit or a vegetable (Food task) or they indicate whether it was small or large (Size task). To account for slower RT in children and older adults, we adjusted the stimulus display times.

Participants

49 CH (mean age: 10.09 , SD = 1.33, range: 9-12)
34 YA (mean age: 23.72 , SD = 4.48, range: 19-34)
33 AD (mean age: 15.29, SD = 1.15, range: 14-16)
28 OA (mean age: 70.66 , SD = 5.03, range: 68-70)

Exclusion criteria: Proportion timeouts > 3WG-SD (3 CH, 2 AD, 1 YA, 2OA); MOCA <= 23 (1 OA)

Regression analyses

Update Rule:

Following recent work, the average reward rate ($\bar{r}$) was calculated using the following update rule [4]:

$$\bar{r} = (1-a)^t \bar{r}_t + [1-(1-a)^t]\frac{R}{t}$$

Where R was the reward obtained on the trial, t was the time elapsed since the previous trial, and α was a learning rate parameter

Learning Rate:

To estimate the learning rate, we conducted subject-specific regressions with α set as a free-parameter:

RT $= \bar{r}$ + R + trial_type + prev_type + prev_error + prev_missed + same_resp + ITI

Using a coarse grid search, we estimated the learning rate that best minimized error (SSE) in the model across each age group separately. Consistent with Otto and Daw's [4] findings, for YA we found a best fitting learning rate of 0.0027. For CH, AD, and OA, we found best fitting learning rates of 0.00200, 0.0009, and 0.0479 respectively.

RT analysis:

Using the lme4 package in R [5], we calculated mixed-effects regressions for the two tasks. All predictors were taken as both fixed and random effects. All continuous variables were within-subject z-scored, and RT was log-transformed.

Task switching task:

RT=age_group + $\bar{r}$ + R + task_type + task_switch + prev_type + prev_error + prev_missed + prev_missed + ITI

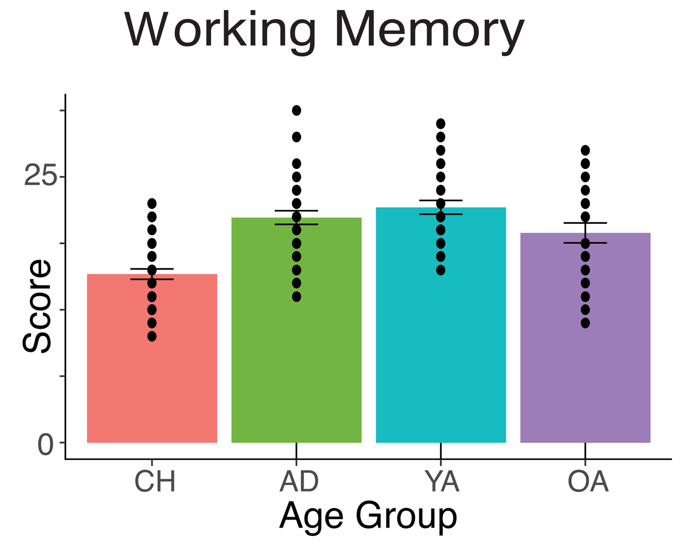
Flanker task:

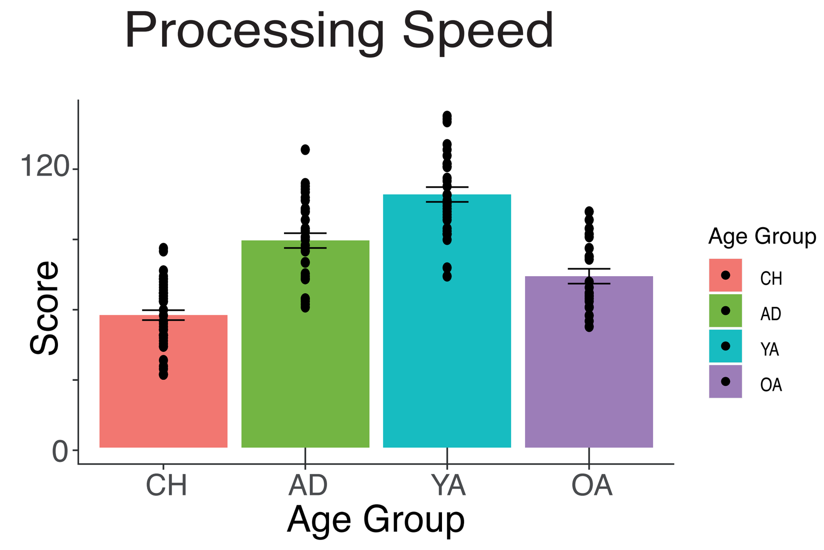
RT=age_group + $\bar{r}$ + R + congruency + prev_type + prev_error + prev_missed + response + ITI

Accuracy analysis:

To explore accuracy, the same procedure was conducted for both tasks using a mixed-effects logistic regression (with the exception of ITI as a predictor in the Flanker regression). A binary accuracy score (correct; incorrect/timeout) was used as an outcome variable.

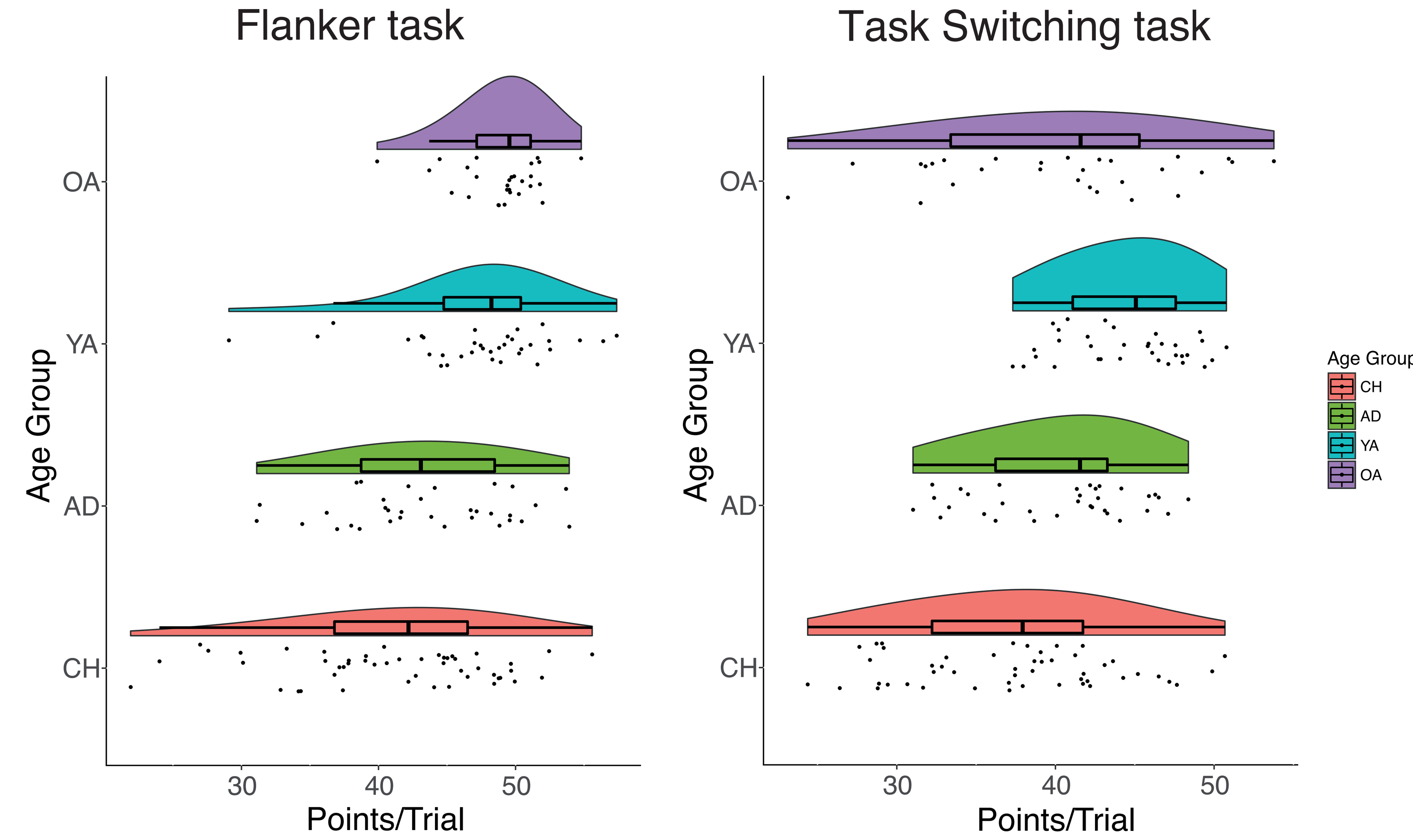
Cognitive Abilities



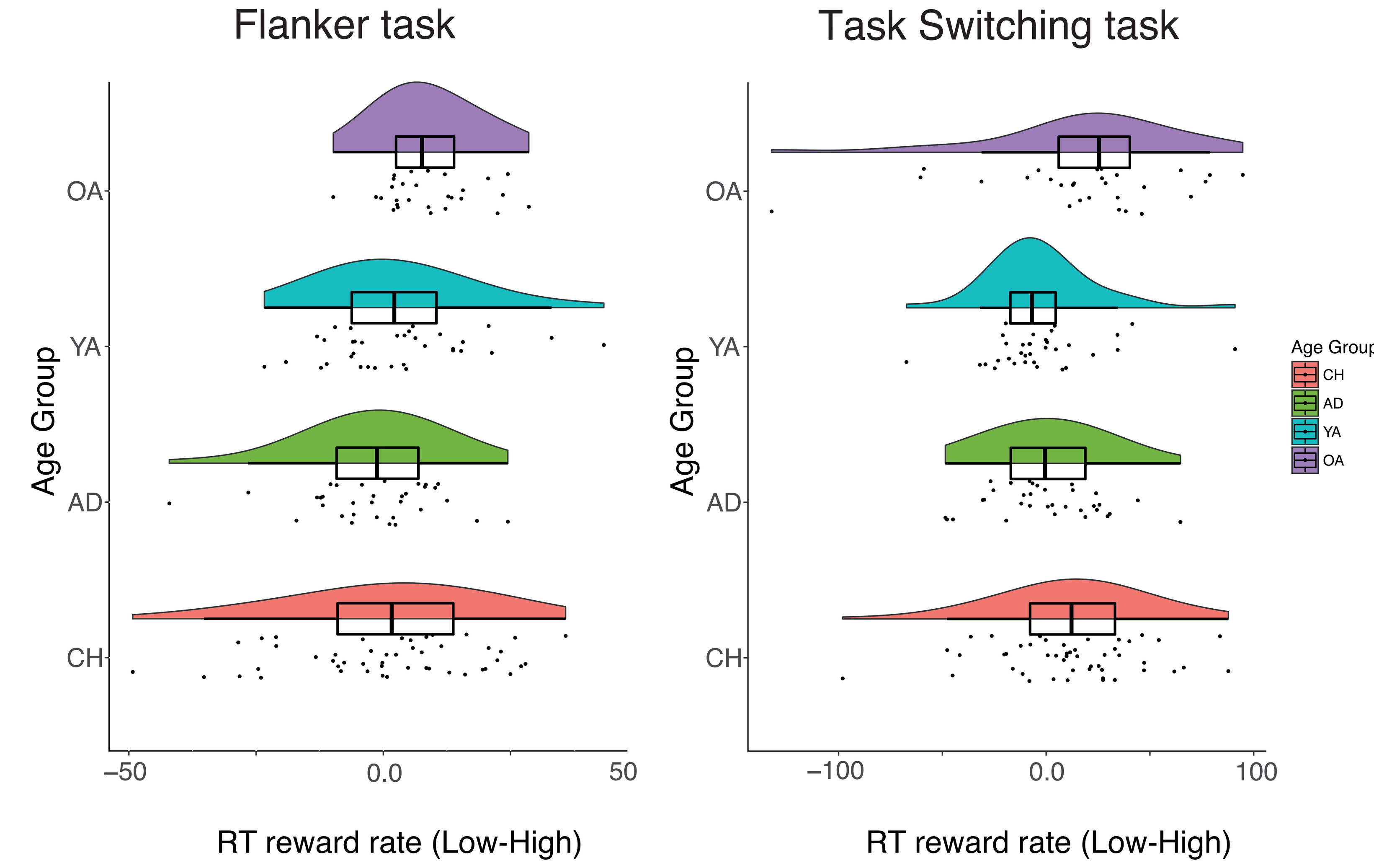


RESULTS

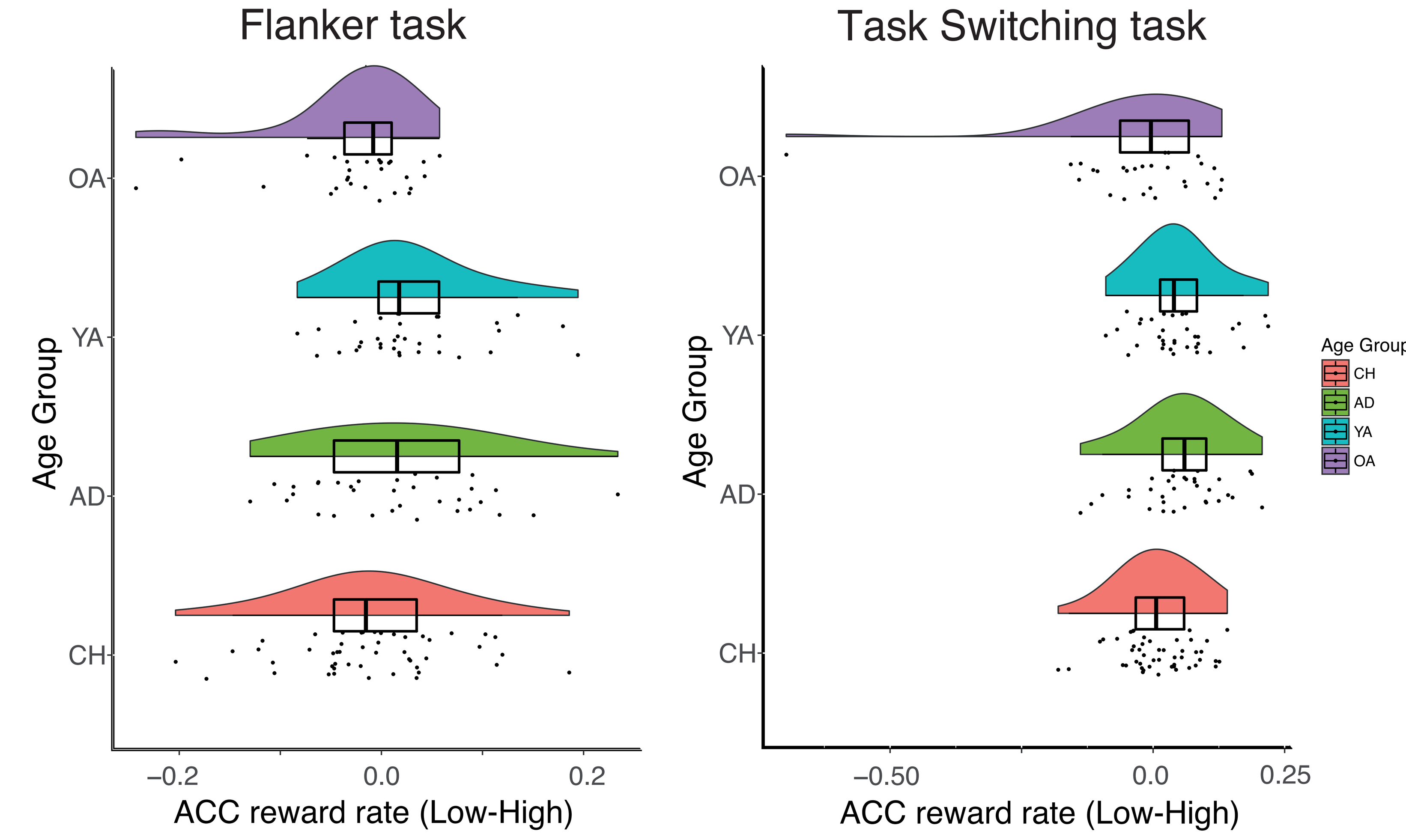
Performance



Reaction Time Reward Rate



Accuracy Reward Rate



DISCUSSION

We found that younger and older adults performed better on the Flanker interference task than children and adolescents. Older adults achieved this by sacrificing faster RT for higher accuracy [6]. However, as task complexity increased (in the task-switching paradigm), this strategy was no longer sufficient and older adults fell to the same performance levels as children and adolescents.

In contrast to our predictions, older adults were more sensitive to changes in reward rate in the Flanker task than any other age group. However, as task complexity increased, children also became sensitive to changes in reward rate. This suggests that when demands on cognitive load reach capacity limitations, participants start to engage in strategic behaviour to optimize performance and thus become more sensitive to changes in reward rates.

In the next step, we place to parametrically increase task difficulty to bring out this sensitivity to changes in reward rate in young adults and adolescents.

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