The Effects of Loss Incentives on Working Memory in Young and Older Adults: A Diffusion Model Analysis

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INTRODUCTION

Older age is accompanied by an increasing threat of losses (e.g., of health, financial security, driving privileges). The opportunity to avoid such losses is often used to motivate behavioral change in older adults.

However, previous studies in our lab suggest that loss-based incentives can impair older adults' performance and motivation on attention and memory tasks (Jang et al., submitted, Lin et al., in revision).

In the present study we extend our previous findings using a different working memory task and further examine the effects of loss incentive on the quality of stimulus representation, the speed-accuracy trade-off, and response bias using diffusion model analyses (Ratcliff, 1978).

Additionally, we manipulate retention interval (4 vs 16 s) to start examining which stage(s) of working memory might be affected by the loss incentive.

To preview, we replicate the previous loss-incentive findings, and find paradoxical effects of retention interval. However, incentive and retention interval effects appear to be independent.

METHODS

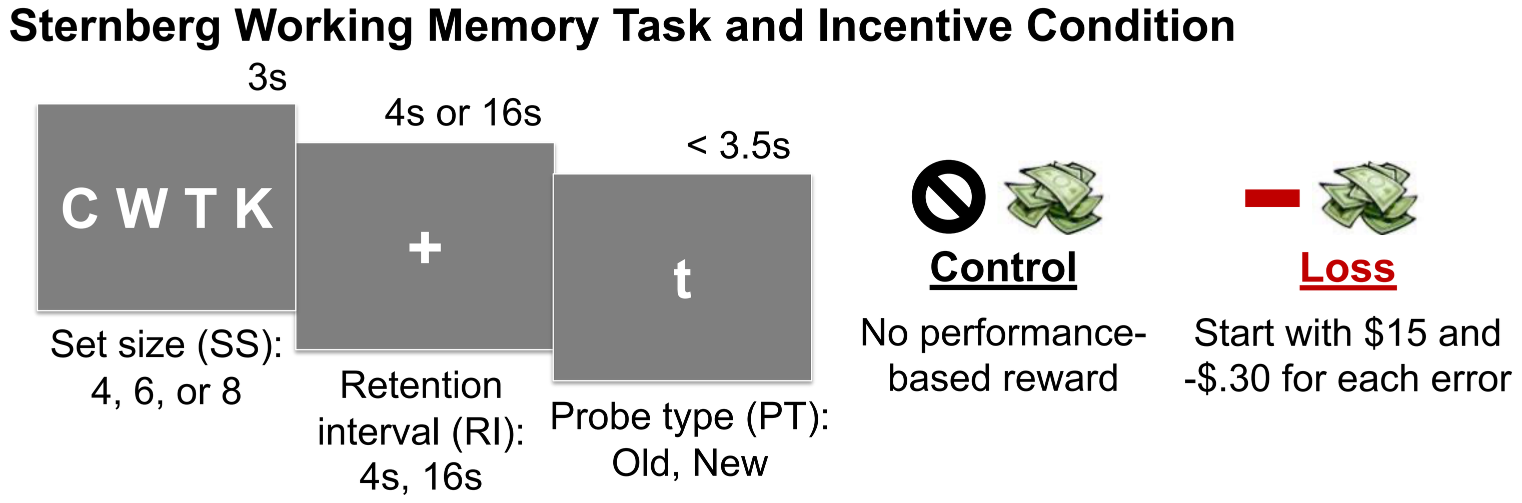
Participants

After screening, younger adults (YA) and older adults (OA) were randomly assigned to either control or loss-based incentive conditions.

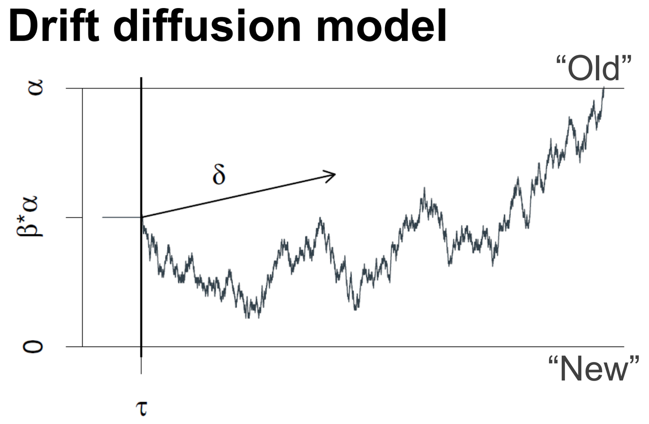
Groups	n (f)	Age	Education (yr)	ERVT	MMSE
YA Control	31 (24)	19.3 (±1.71)	13.3 (±1.43)	17.6 (±5.83)	NA
YA Loss	34 (26)	19.6 (±2.13)	13.6 (±1.91)	20.0 (±4.73)	NA
OA Control	23 (16)	69.2 (±4.67)	17.7 (±1.79)	31.1 (±7.07)	28.7 (±0.96)
OA Loss	28 (15)	68.0 (±5.75)	17.7 (±1.94)	29.8 (±7.29)	28.7 (±1.22)

f: female; ERVT: Extended Range Vocabulary Test (Ekstrom et al., 1976); MMSE: The Mini-Mental State Examination (Folstein et al., 1983)

Sternberg Working Memory Task and Incentive Condition



Drift diffusion model



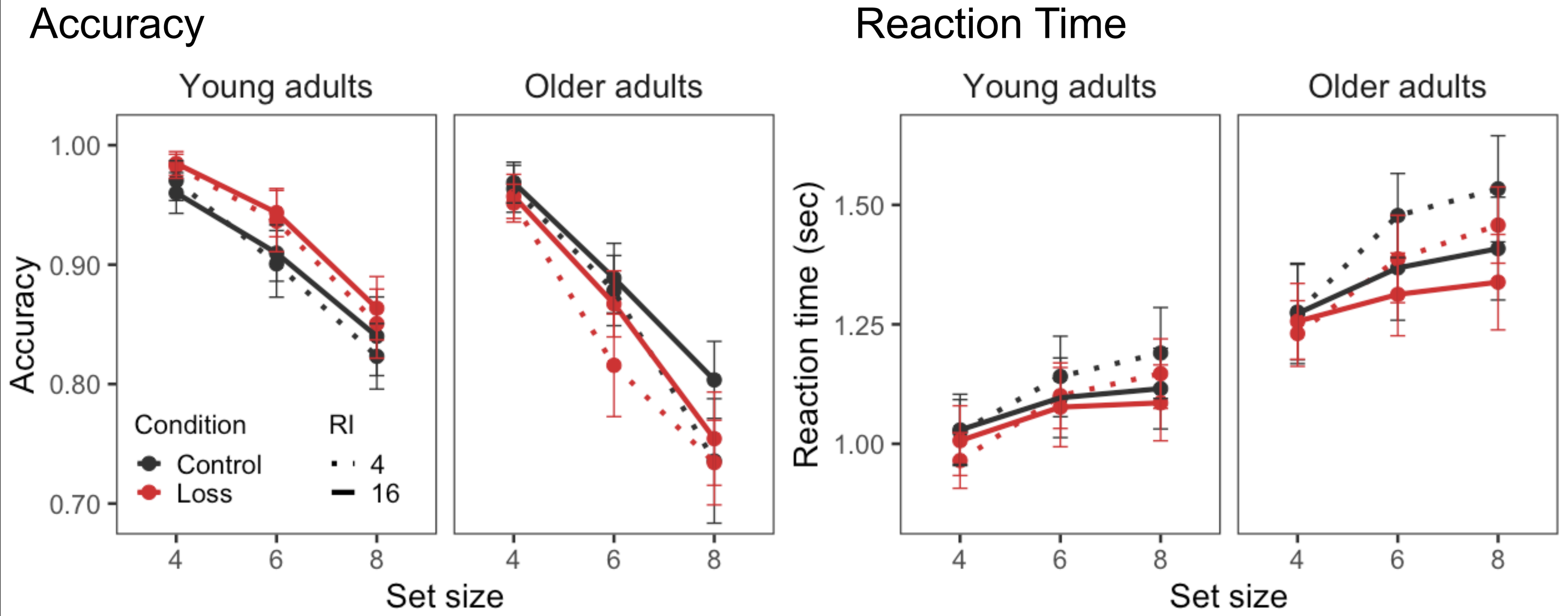
Drift diffusion models integrate accuracy and response time data to understand decisions in two-choice tasks (Ratcliff, 1978). Model parameters are interpreted in terms of the processes described in the table below (Wabersich & Vandekerckhove, 2014).

δ	Drift rate	Quality of the stimulus representation
α	Boundary separation	Speed-accuracy trade-off (high α = high accuracy)
β	Initial bias	Response bias (β > 0.5 bias towards "old" response)
τ	Non-decision time	Motor response time, encoding time

Drift rate ~ PT * SS * RI * Age * Incentive + (1|ID)
Boundary separation ~ SS * RI * Age * Incentive + (1|ID)
Bias ~ SS * RI * Age * Incentive + (1|ID)
Non-decision time ~ Age * Incentive + (1|ID)

We used a hierarchical Bayesian approach to fit the data. The model formula is specified on the left.

PERFORMANCE



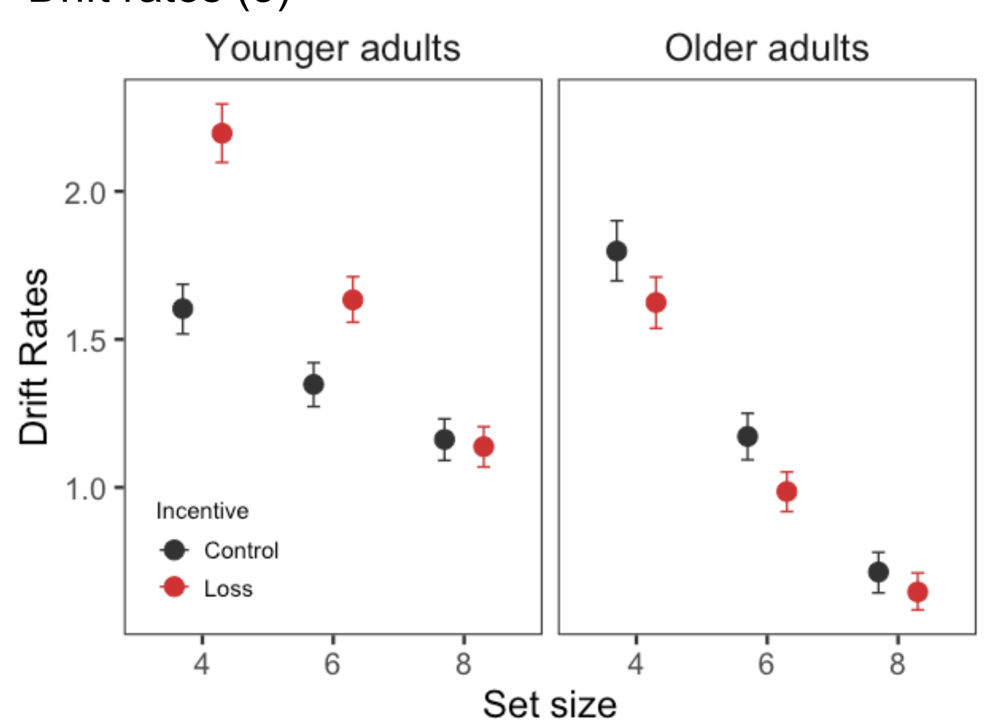
Loss incentive increased accuracy in younger adults, β = 0.50 [0.07 0.93], **but decreased accuracy in older adults**, β = -1.01 [-1.58 -0.41]. Loss incentive did not significantly affect or interact with age for reaction time.

Longer retention interval reduced reaction time, β = -0.04 [-0.08 -0.01]. This effect was stronger for older adults, β = -0.06 [-0.12 -0.01]. Retention interval did not have a significant impact on overall accuracy, nor interact with other factors.

What explains incentive and retention interval effects? Does loss incentive/retention interval change the quality of stimulus representation, change emphasis on speed vs accuracy, or move decision bias towards a certain response?

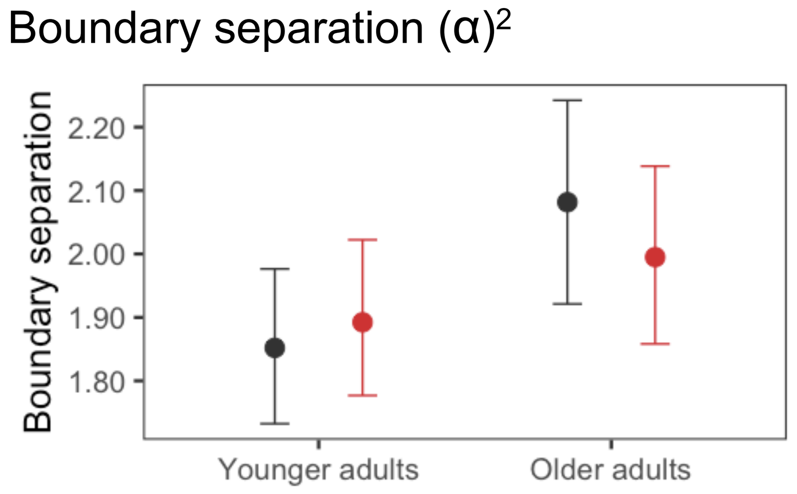
DIFFUSION MODEL ANALYSIS: INCENTIVE EFFECT

Drift rates (δ)[1]



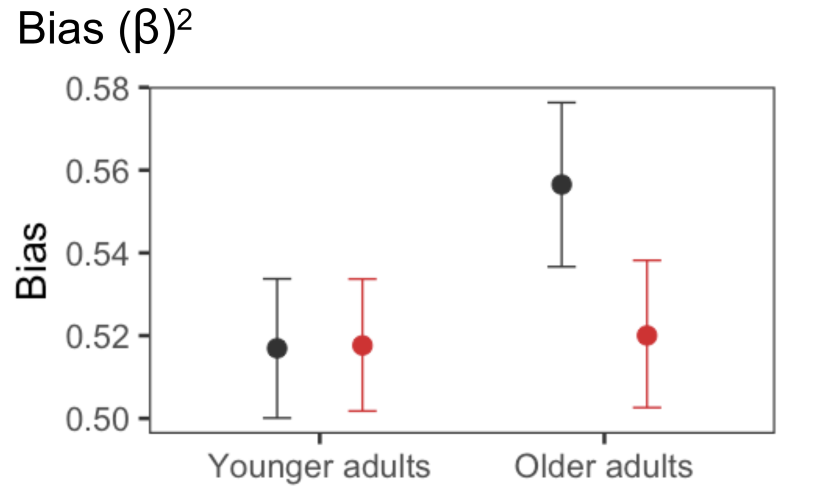
For young adults, loss incentive led to stronger drift rates at set size 4, δ_{Diff} = 0.59 [0.48 0.70], and set size 6, δ_{Diff} = 0.29 [0.20 0.38], but not at set size 8, δ_{Diff} = -0.02 [-0.11 0.06]. **In contrast, for older adults, loss incentive led to weaker drift rates** at set size 4, δ_{Diff} = -0.17 [-0.29 -0.06], and set size 6, δ_{Diff} = -0.19 [-0.27 -0.10], but marginally at set size 8, δ_{Diff} = -0.07 [-0.14 0.01].

Boundary separation (α)[2]



Loss incentive did not change speed-accuracy tradeoffs in either younger, α_{Diff} = 0.04 [-0.10 0.19], or older adults, α_{Diff} = -0.09 [-0.27 0.09].

Bias (β)[2]

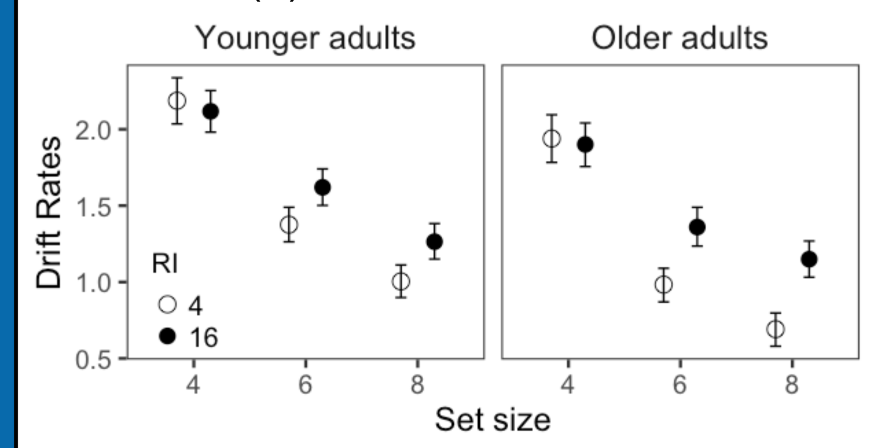


Loss incentive did not change bias for young adults, β_{Diff} = 0.0006 [-0.02 0.02]. **For older adults, loss incentive reduced bias towards making an "old" response,** β_{Diff} = -0.04 [-0.06 -0.01].

[1]Results for the drift rates did not qualitatively differ across different levels of the probe type or retention interval factors and therefore were collapsed over those factors. Because drift rates for the "new" response (the lower boundary) are negative values, absolute values were used for easier comparison. [2]Results for boundary separation and bias did not differ across set size or and retention interval and thus are shown collapsed across those factors,.

DIFFUSION MODEL ANALYSIS: RETENTION INTERVAL EFFECT

Drift rates (δ) for new letter trials[3]



Longer retention intervals led to stronger drift rates for new letter trials at set size 6, δ_{Diff} = 0.31 [0.22 0.40], and set size 8, δ_{Diff} = 0.36 [0.27 0.45], but not at set size 4, δ_{Diff} = -0.05 [-0.17 0.06].

This pattern was not observed in old letter trials (data not shown).

[3]Drift rates did not qualitatively differ across incentive condition and are thus shown collapsed over that factor. For the ease of comparison, we report absolute values for all drift rates on the plots.

CONCLUSIONS

Loss incentive increased accuracy and motivation (data not shown) for young adults but decreased it for older adults. This replicates our previous findings.

Diffusion modeling suggested that the opposite effects of the incentive on accuracy in the two age groups can be explained by effects on the quality of the stimulus representation (drift rate).

The lack of interaction between incentive and retention interval suggests that incentive affects processes at encoding.

Unexpectedly, longer retention intervals did not reduce accuracy. Instead, they led to paradoxically *faster* reaction times, especially for older adults.

Diffusion modeling suggested that the beneficial effects of longer retention intervals might be explained by increases in the quality of the stimulus representation, especially on new letter trials.

It may seem counterintuitive that retention interval processes (e.g., rehearsal) affecting stimulus quality have a stronger impact on new letter trials. A potential explanation is that fast correct rejections require high-quality representations of the studied items. In contrast, for old-letter trials, the (re)presentation of the probe item may provide a "copy cue" (Tulving, 1983) whose strength overrides that of the memory set representation.

Diffusion model analyses provided further insights into the processes underlying both our expected effects of incentive and the unexpected effects of retention interval.

Physiological and neural measures may provide further tests of these ideas.

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