

Experimental manipulations of intertemporal choice: successes and limitations

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Science of Behavior Change Grand Rounds

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Intertemporal choices

Choices between smaller-sooner rewards
and larger-later rewards

Temporal discounting

The tendency for people to
discount the value of delayed
rewards as the delay to
receiving them increases

Temporal discounting as a mechanism of behavior change

- Lapses in self-regulation may stem from people *undervaluing the future*

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Temporal discounting as a mechanism of behavior change

- Lapses in self-regulation may stem from people *undervaluing the future*
- If this is the case, then temporal discounting *rates* should be related to real-world behaviors

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Temporal discounting is associated with...

- Drug and alcohol abuse and addiction (Amlung et al., 2017)
 - Related to severity (Amlung et al., 2017)
 - Predicts treatment success (Washio et al., 2011; Sheffer et al., 2014)
- Other forms of psychopathology
 - ADHD (Jackson & MacKillop, 2016)
 - Pathological gambling (Miedl et al., 2015)
 - Schizophrenia (Yu et al., 2017)
 - Borderline personality disorder (Barker et al., 2015)
 - Eating disorders (McClelland et al., 2016)
- Overeating (Jarmolowicz et al., 2014)
- (Not) Exercising (Sweeney & Culcea, 2017; Tate et al., 2015)
- Texting while driving (Hayashi et al., 2018)
- Excessive credit card borrowing (Meier & Sprenger, 2010)

Temporal discounting as a mechanism of behavior change

- Lapses in self-regulation may stem from people *undervaluing the future*
- If this is the case, then temporal discounting *rates* should be related to real-world behaviors
- ...and changing temporal discounting should result in changes in real health behaviors

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?

Talk outline

- How is temporal discounting measured and quantified in the lab?
- What do we know about how temporal discounting can be manipulated in the lab?
 - Framing effects vs. incidental/carryover effects
- Future directions and open questions

Measuring temporal discounting

\$11
today

\$35
35 days

Measuring temporal discounting

\$24
today

\$25
112 days

Measuring temporal discounting

\$14	\$30
7 days	28 days

At the end, participant may or may not receive what they chose on one randomly selected trial (depends on the design).

Measuring temporal discounting

Titration

Please choose one option in each row.

- | | |
|----------------------------------------------|----------------------------------------------------|
| <input checked="" type="radio"/> \$ 50 today | <input type="radio"/> \$ 55 in 3 months |
| <input checked="" type="radio"/> \$ 50 today | <input type="radio"/> \$ 60 in 3 months |
| <input type="radio"/> \$ 50 today | <input checked="" type="radio"/> \$ 65 in 3 months |
| <input type="radio"/> \$ 50 today | <input checked="" type="radio"/> \$ 70 in 3 months |
| <input type="radio"/> \$ 50 today | <input checked="" type="radio"/> \$ 75 in 3 months |
| <input type="radio"/> \$ 50 today | <input checked="" type="radio"/> \$ 80 in 3 months |

Next

Adjusting Titration

\$10 now · \$30 7 days

\$10 now · \$25 7 days

\$10 now · \$20 7 days

Randomized-choice

\$10 now · \$30 7 days

\$35 30 days · \$12 now

\$16 now · \$25 10 days

- All discounting tasks try to assess indifference points, or what amount of money today feels subjectively equivalent to a larger amount of money in the future

Quantifying temporal discounting: Hyperbolic model

$$SV = \frac{A}{1 + kD}$$

The diagram illustrates the hyperbolic discounting model equation $SV = \frac{A}{1 + kD}$. The variables are defined by callouts: SV is the Subjective value of delayed reward; A is the Amount of delayed reward; k is the Discount rate parameter; and D is the Delay (days).

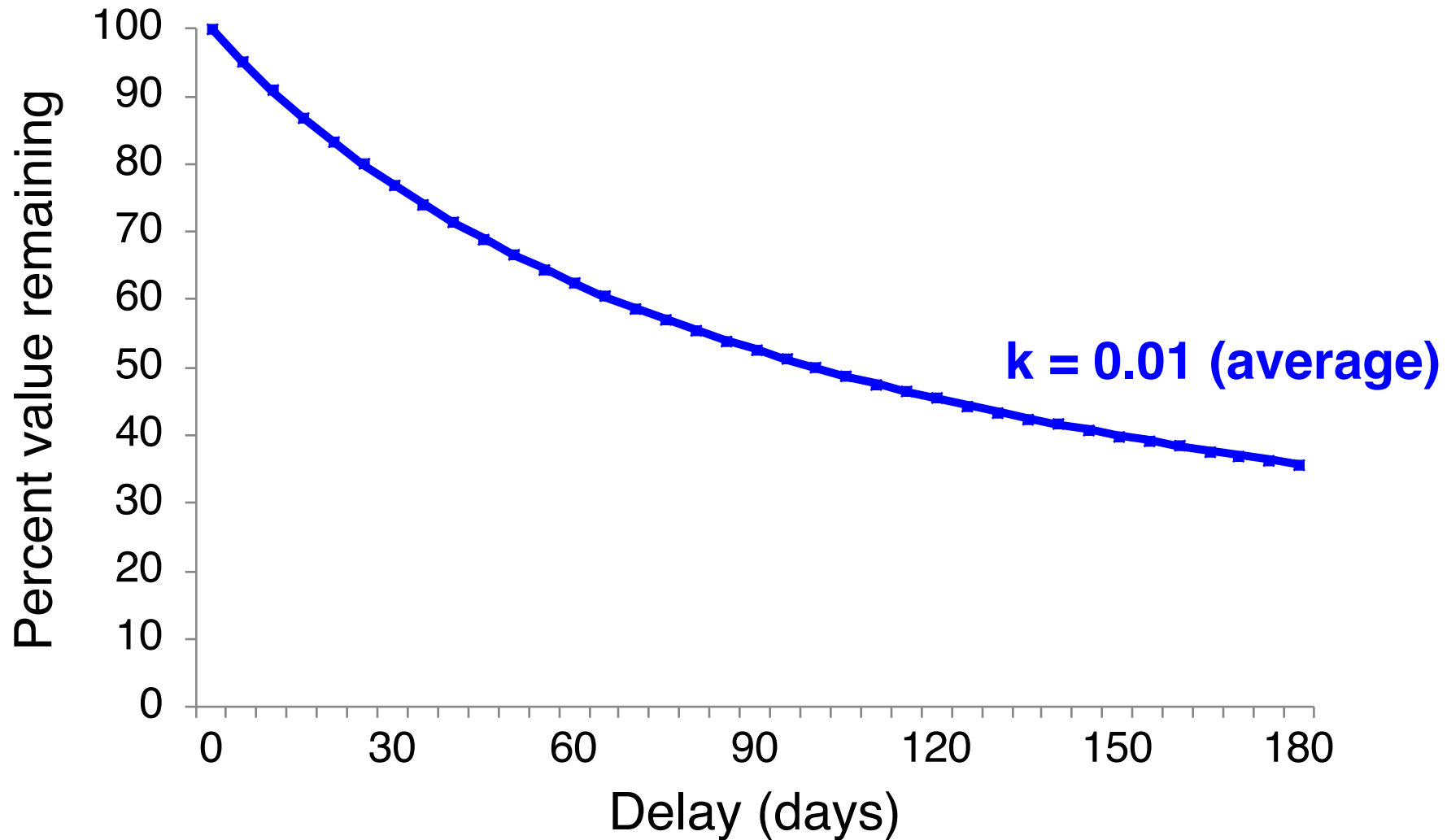
“k” parameter = rate at which value of delayed reward gets discounted in time,

signifies degree of impulsivity.

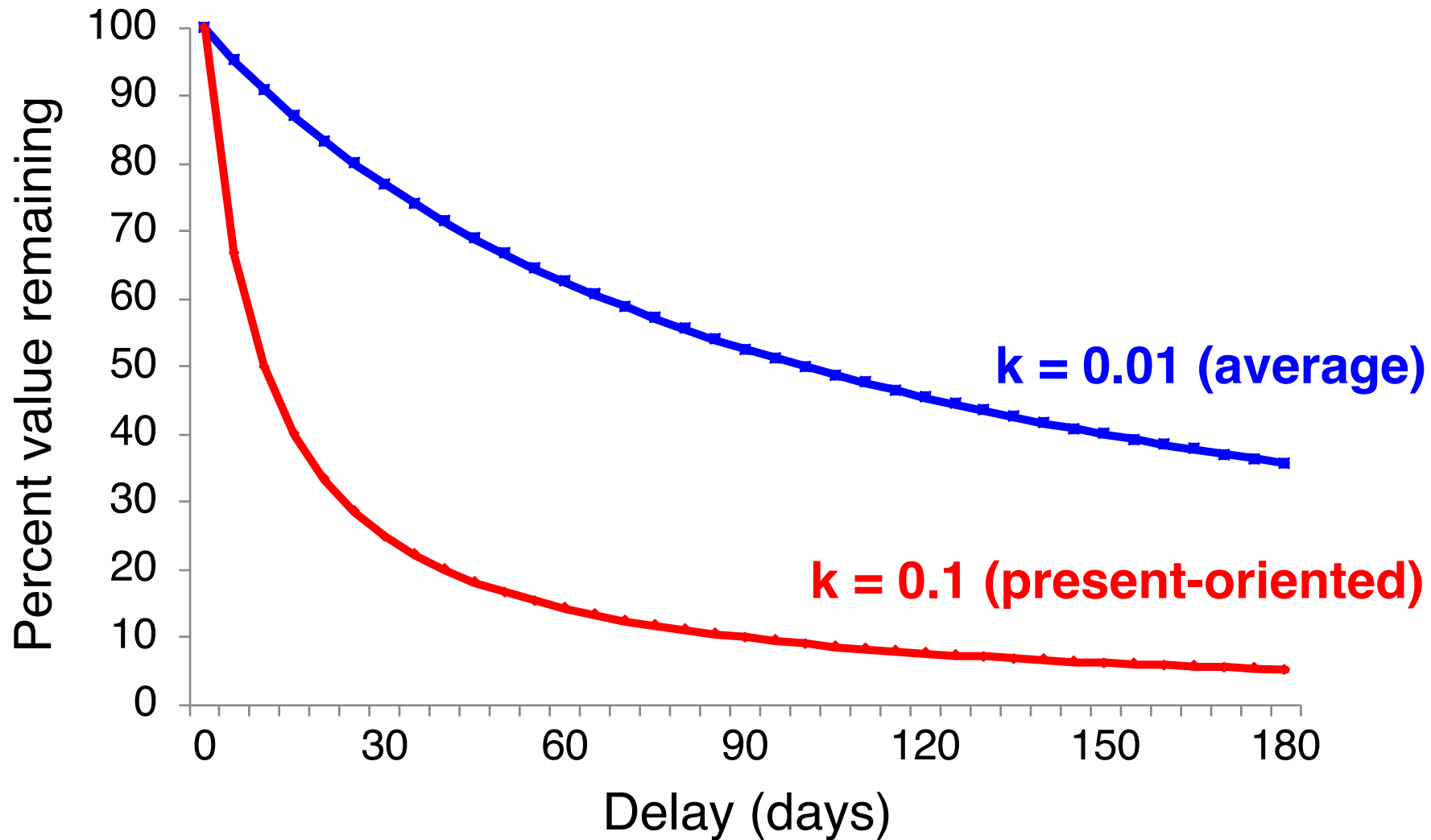
Higher k = more impulsive (present-oriented)

Lower k = more patient (future-oriented)

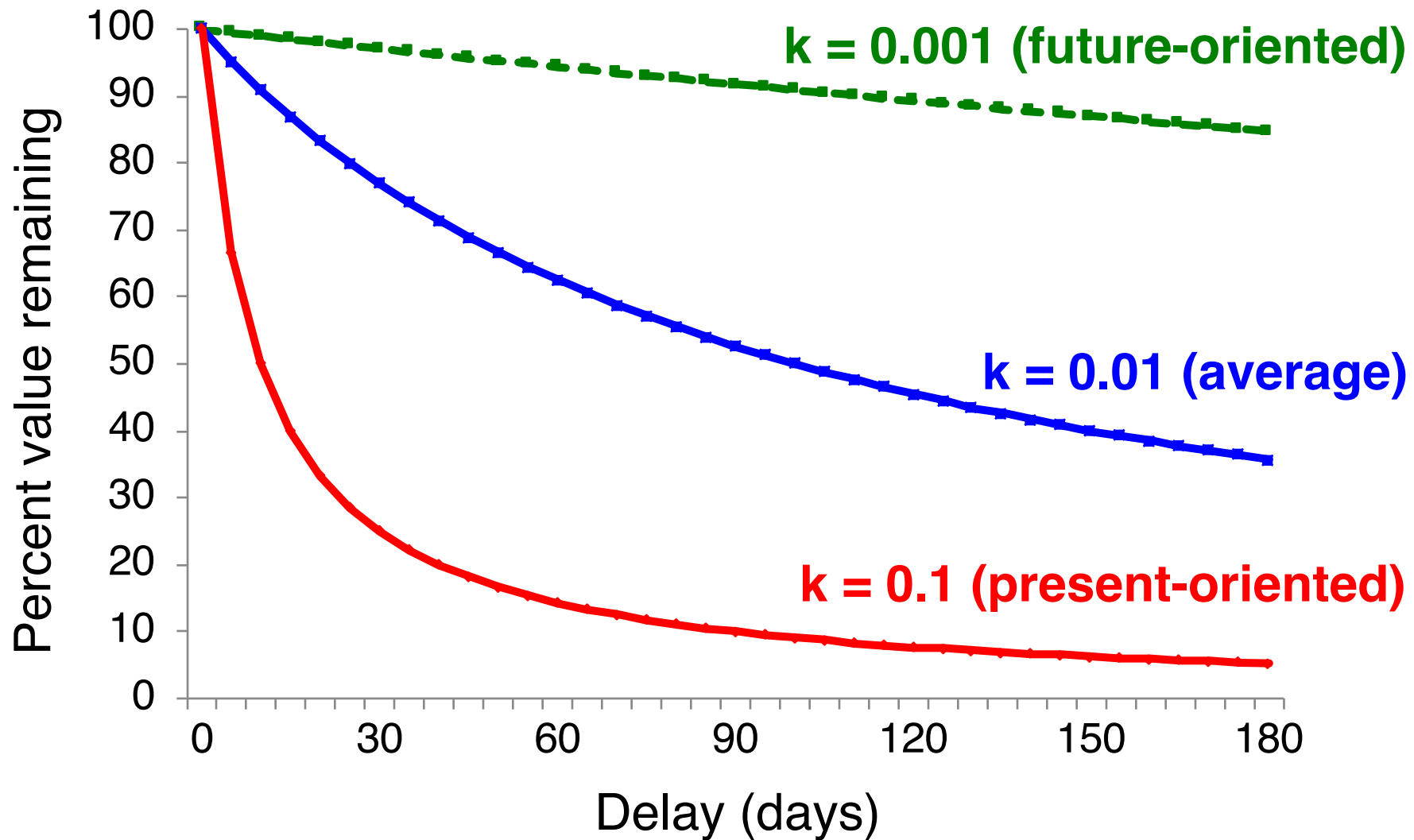
Sample hyperbolic discounting curves



Sample hyperbolic discounting curves



Sample hyperbolic discounting curves



Summary: measuring temporal discounting

- Temporal discounting is generally measured by having people make choices between smaller/sooner and larger/later monetary rewards
- It can be quantified in a number of ways, but the most common way assumes that the relationship between value and delay is hyperbolic
- Temporal discounting rates are relatively stable over time, suggesting that it can potentially be used as a behavioral marker, especially for impulsive disorders
- But it would also be useful to manipulate temporal discounting...

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Ways to manipulate intertemporal choice

Framing effects

Changing the way a choice is framed or a question is posed

Incidental, or “carryover,” effects

Changing the state or strategy of the decision-maker at the time of choice without changing the presentation of the choice itself

Lempert & Phelps, 2016, *TiCS*
see: Rung & Madden 2018, *JEP: General*

Framing effects

- Initially described in choices under risk (Kahneman & Tversky)
- Example: “Default” bias = when you specify a default, people are more likely to choose it (e.g., “opt-out” for 401k contributions and organ donations)

How can we specify defaults in intertemporal choices, in order to promote more patient behavior?

Delay/speedup asymmetry effect



from Reeck, Wall & Johnson, 2017

People are more willing to wait for delayed rewards if they are asked whether they would like to “speed up” a delayed reward instead of “delay” a more immediate reward.

Loewenstein, 1988; Weber et al., 2007

Other framing effects include:

- Making the opportunity cost of choosing the immediate reward more explicit (Radu et al., 2011)



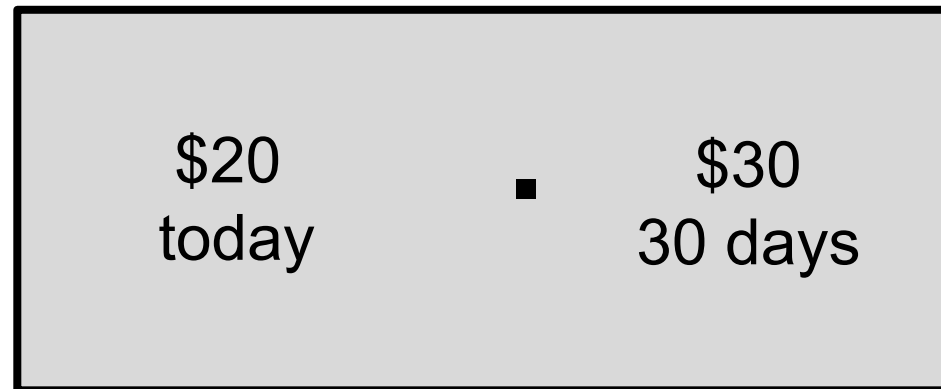
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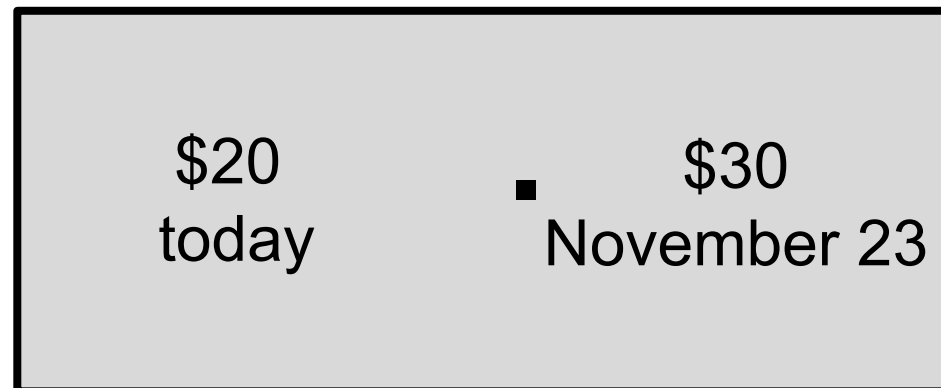
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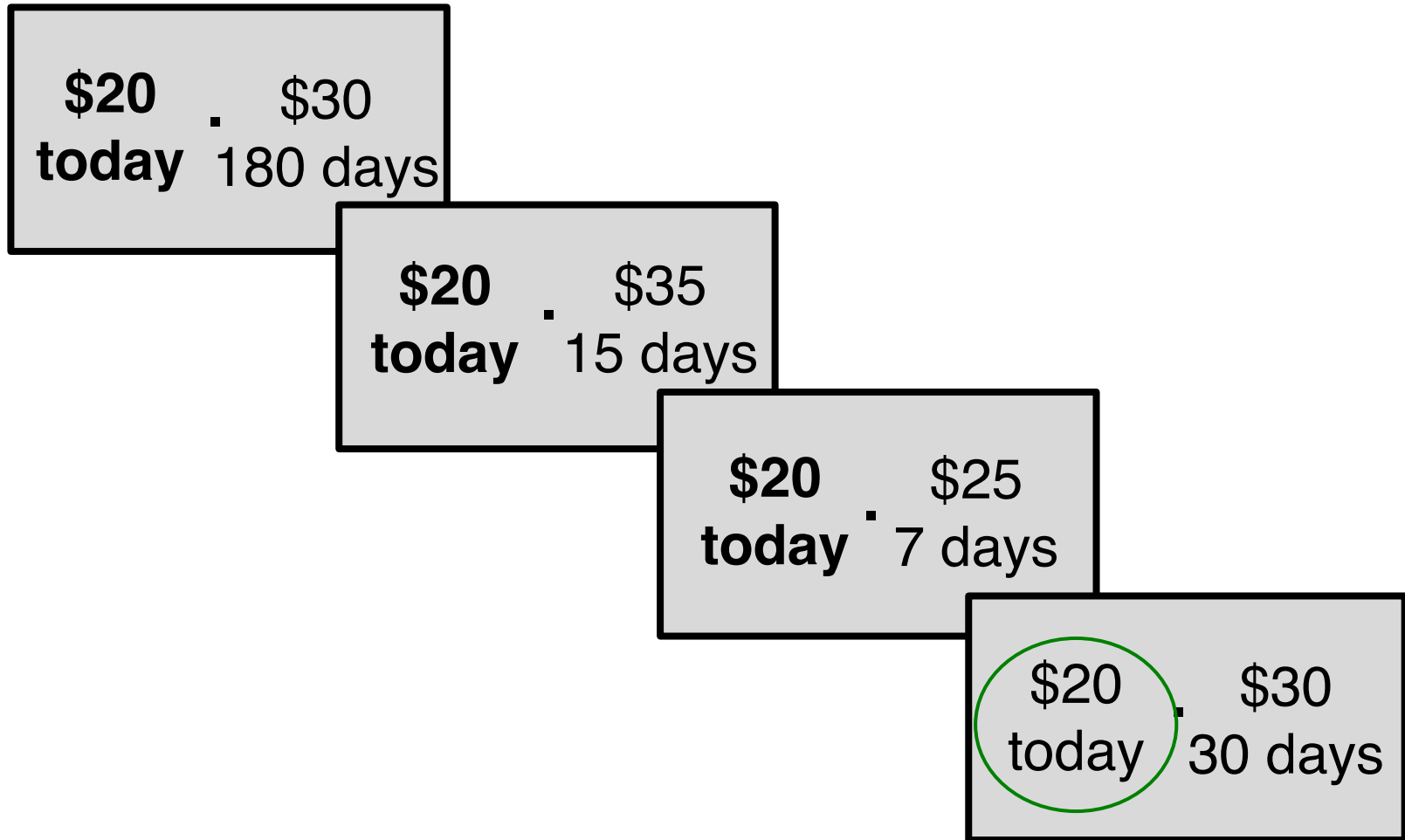
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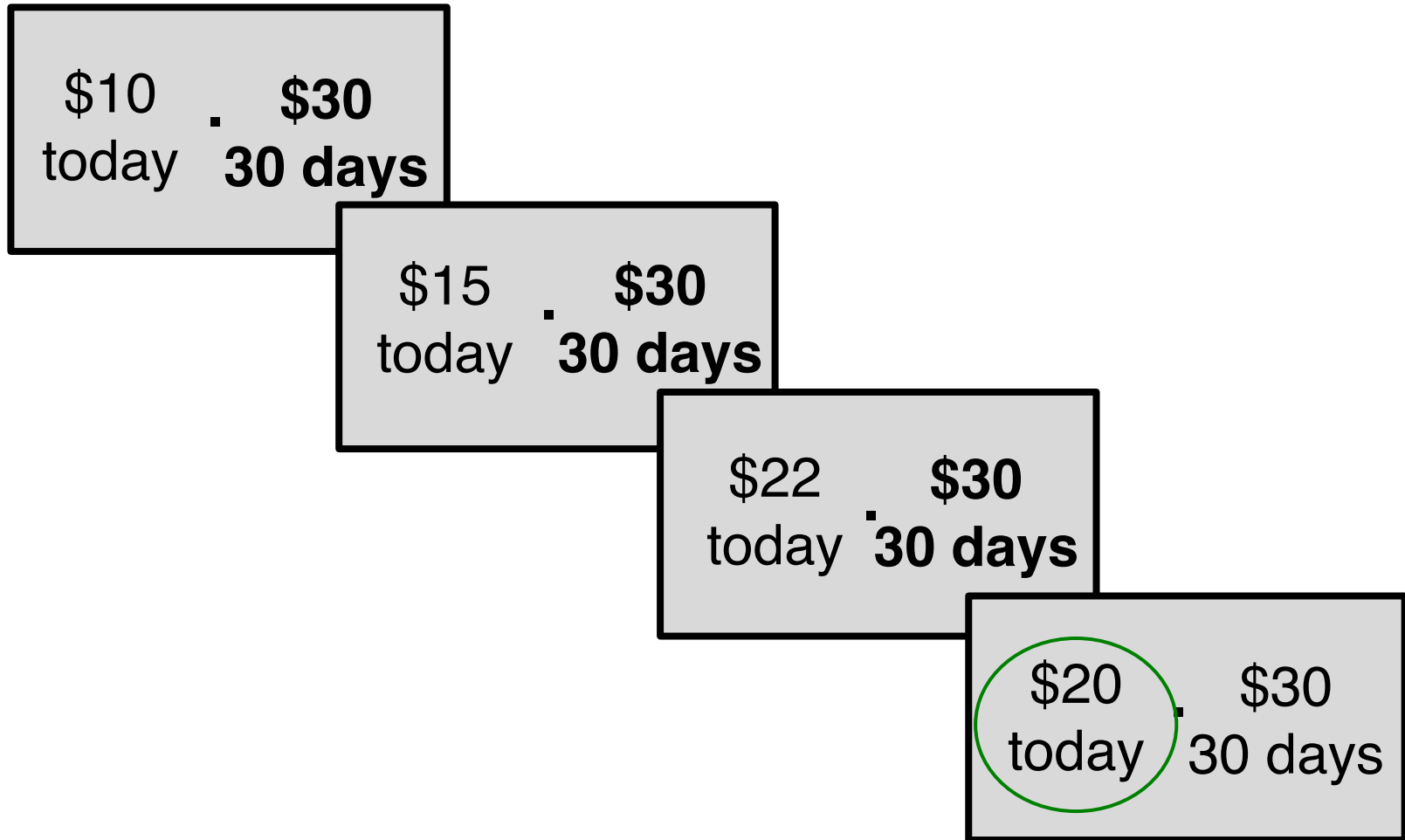
Other framing effects include:

- Making the opportunity cost of choosing the immediate reward more explicit
- Changing how the time interval is framed (e.g., days vs. date; months vs. days).
- Default options can even be specified implicitly by making one option more variable than the other

The recent history of offers creates implicit defaults



The recent history of offers creates implicit defaults



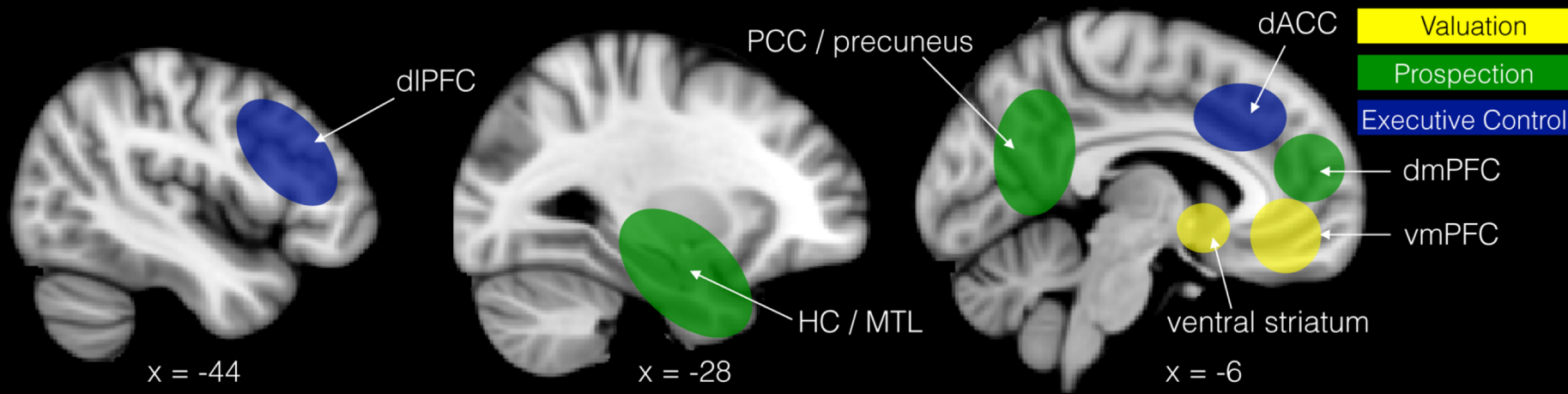
Framing effects: future directions

- How do people form their own defaults, and how can we influence that process?
- Individual differences in susceptibility to framing effects (e.g., [Reeck et al., 2017](#): the way people process intertemporal choices affects how susceptible they are to delay/speedup asymmetry effect)

But we can't always control how the choice is framed...

- So can we change people's state of mind when they are making the choice, or introduce strategies for them to flexibly apply when they are making the choice?
- These are known as incidental, or "carryover," effects
- This category also includes training interventions, since they are incidental to the choice itself

Neurocognitive systems involved in intertemporal choice



- **Valuation:** to the extent the reward is valued, you will see activation there (“final stage” before choices are made)
- **Executive control:** cognitive flexibility, working memory, inhibitory control
- **Prospection / memory:** episodic and semantic memory, episodic future thinking

Candidate neurocognitive systems mediating individual differences

Executive Function

- **Processes:** Cognitive flexibility, working memory
- **Mechanism:** May support patient choice through inhibition of impulsive responses
- **Neural evidence:** integrity of frontostriatal circuits related to discount rate; more activity in exec function regions during delayed reward choice

Declarative memory

- **Processes:** Episodic and semantic memory, prospection
- **Mechanism:** May support patient choice by helping individuals imagine themselves in the future
- **Neural evidence:** medial temporal lobe gray matter volume and white matter integrity related to discount rate

Which mediates individual differences in temporal discounting: executive function or declarative memory?

Older adult participants

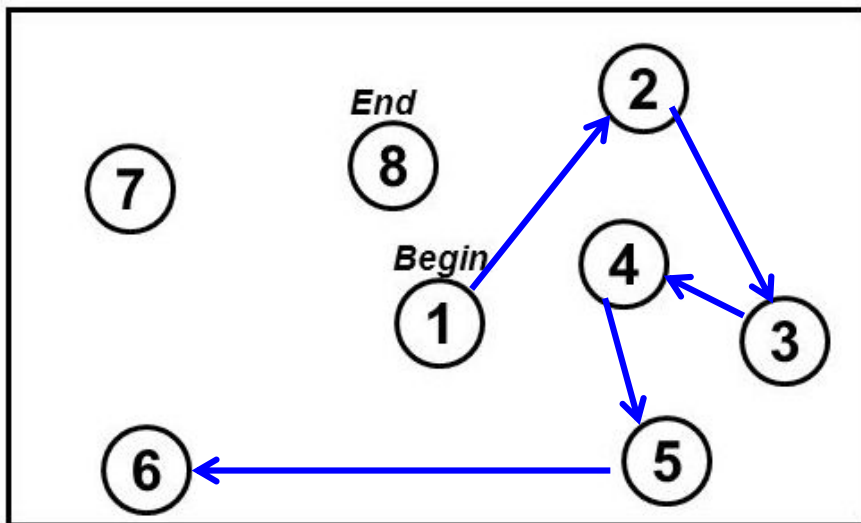
Demographics:

- 100 participants
- ages 59-94
- mean age = 72.4; SD = 6.82
- 74 cognitively normal, 26 MCI
- 63 White, 35 Black, 2 Multi-Racial
- From a longitudinal cohort at the Penn Memory Center, a full neuropsychological testing battery is done every year.

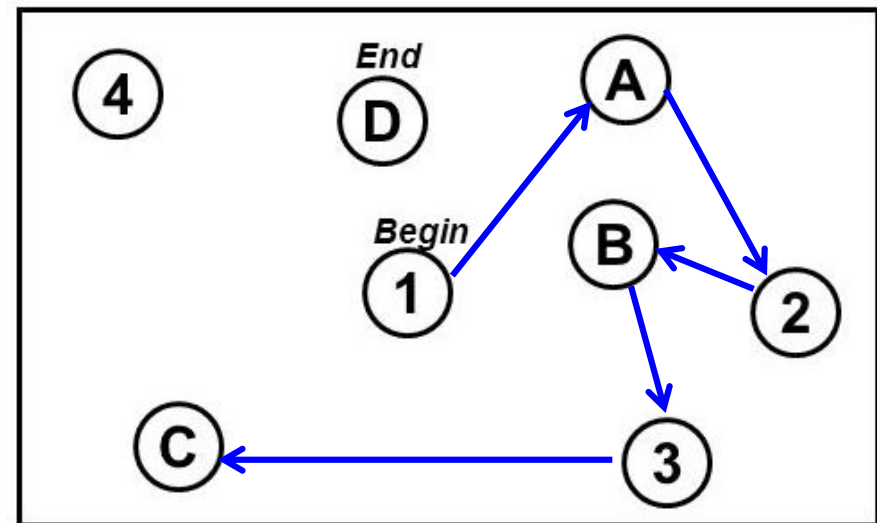
Executive function measures

1. Trail Making Test: difference in RT between Part B and Part A

Part A



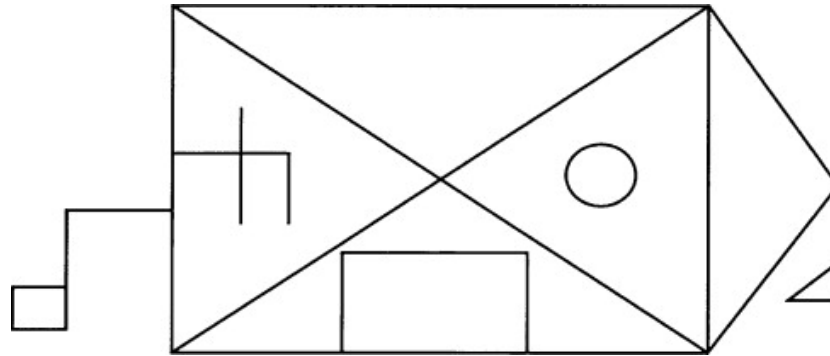
Part B



2. Lexical fluency: generating as many words beginning with a certain letter (e.g., "L") in one minute

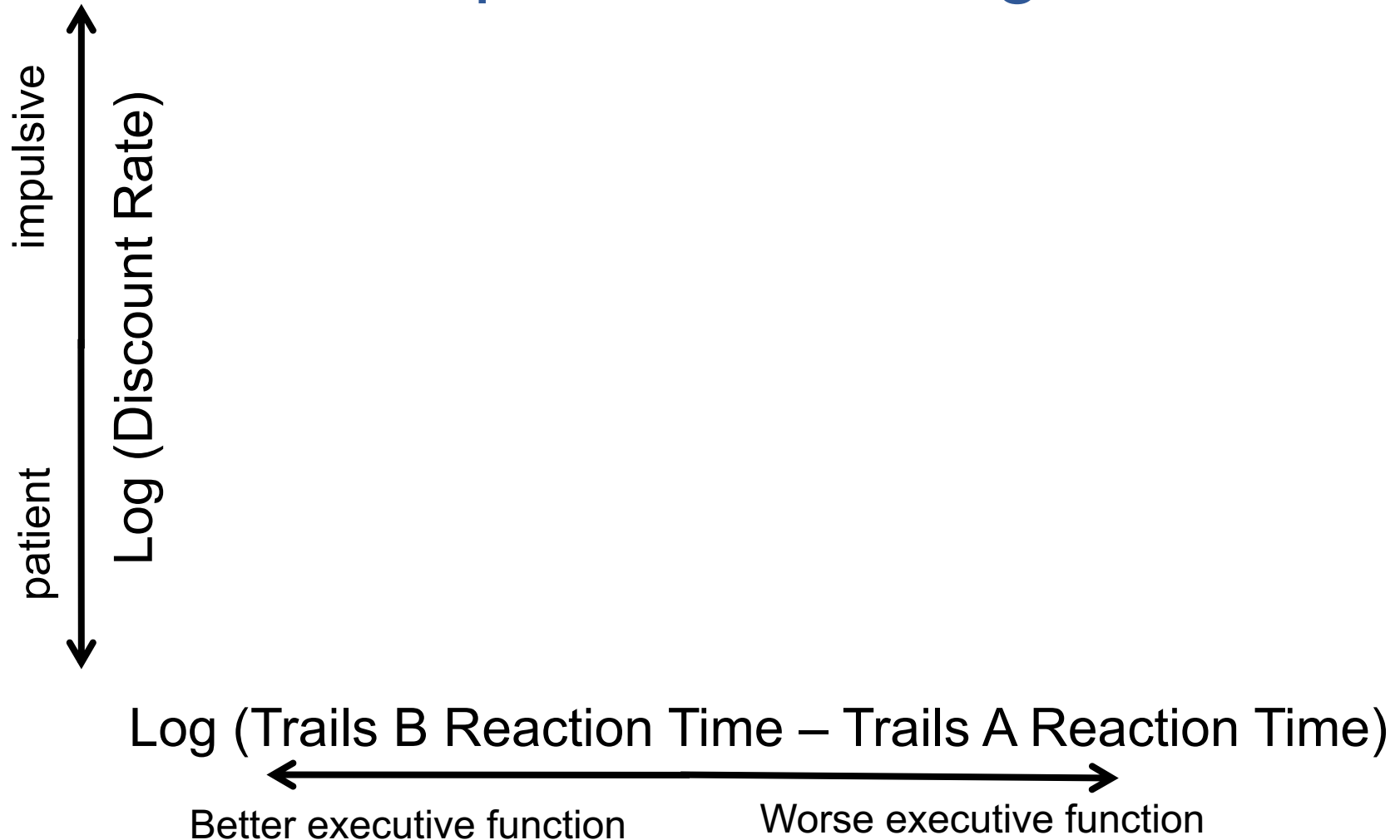
Memory measures

1. Composite of 3 delayed recall measures: Word List Delayed Recall (Verbal), Craft Story Delayed Recall (Narrative), Benson Complex Figure Delayed Recall (Visuospatial)

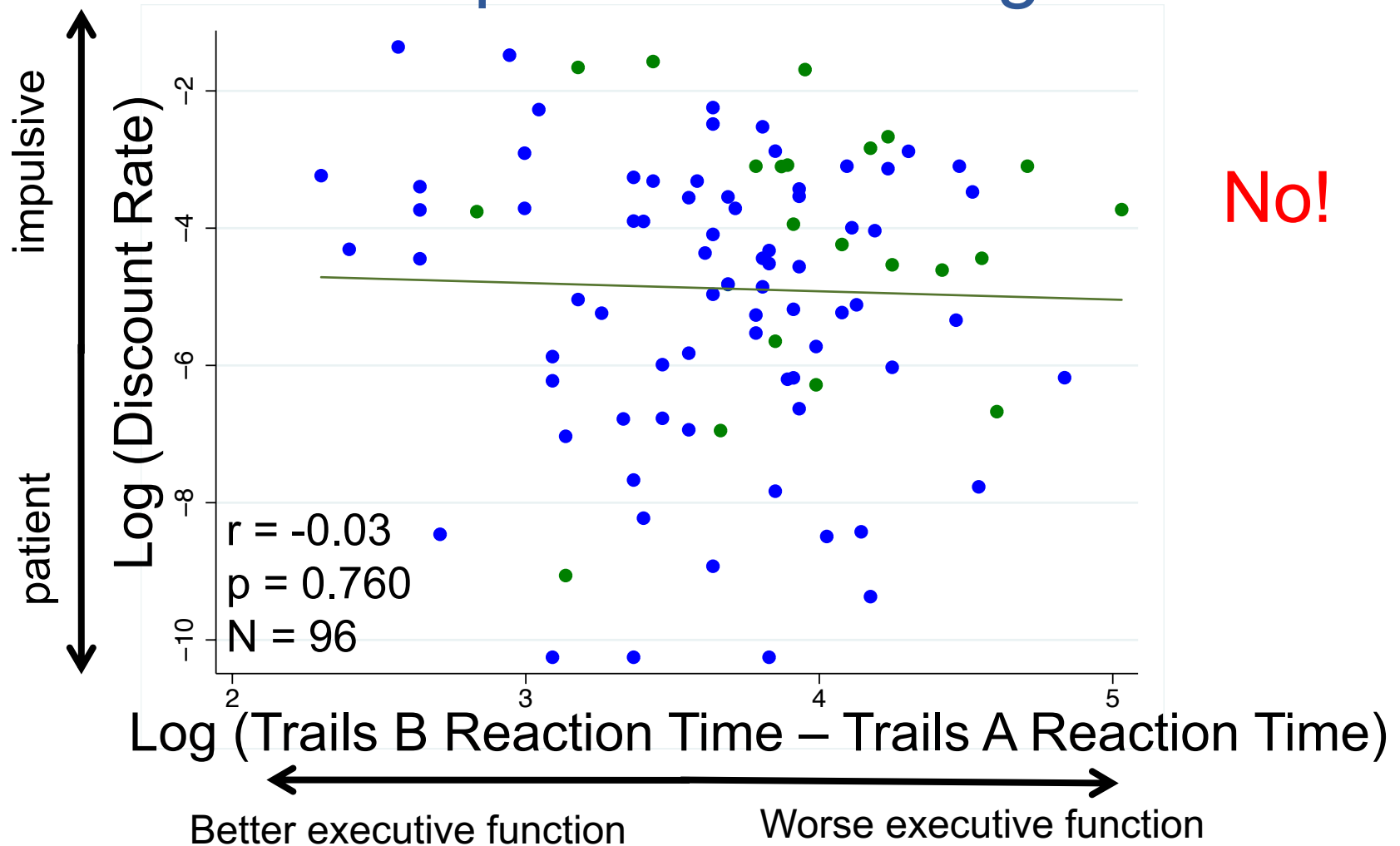


1. Semantic fluency: generating as many exemplars from a category (e.g., animals) as possible in one minute

Does better executive function correlate with lower temporal discounting?



Does better executive function correlate with lower temporal discounting?

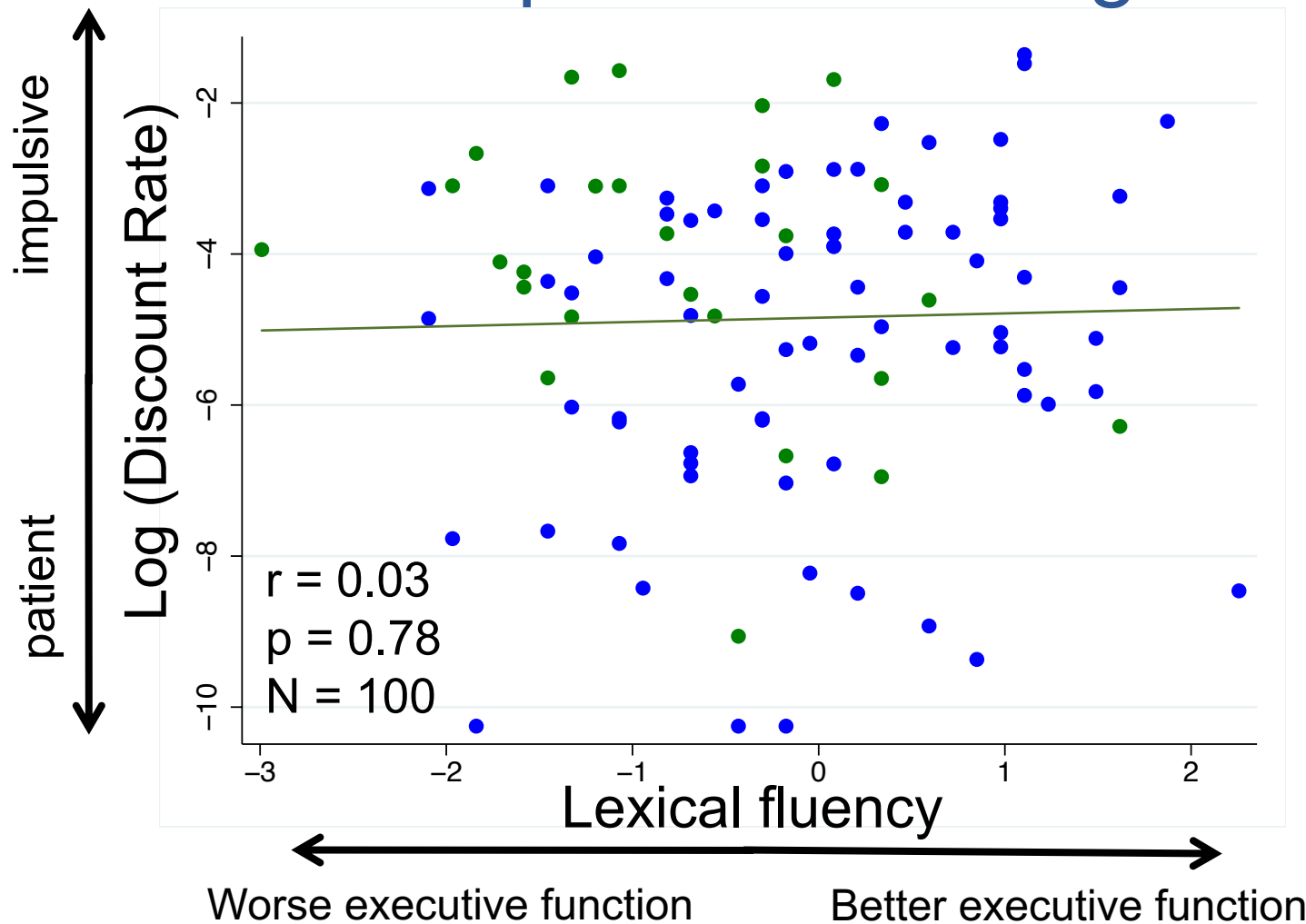


Green = MCI

Blue = Cognitively normal

Lempert, Wolk & Kable, submitted

Does better executive function correlate with lower temporal discounting?



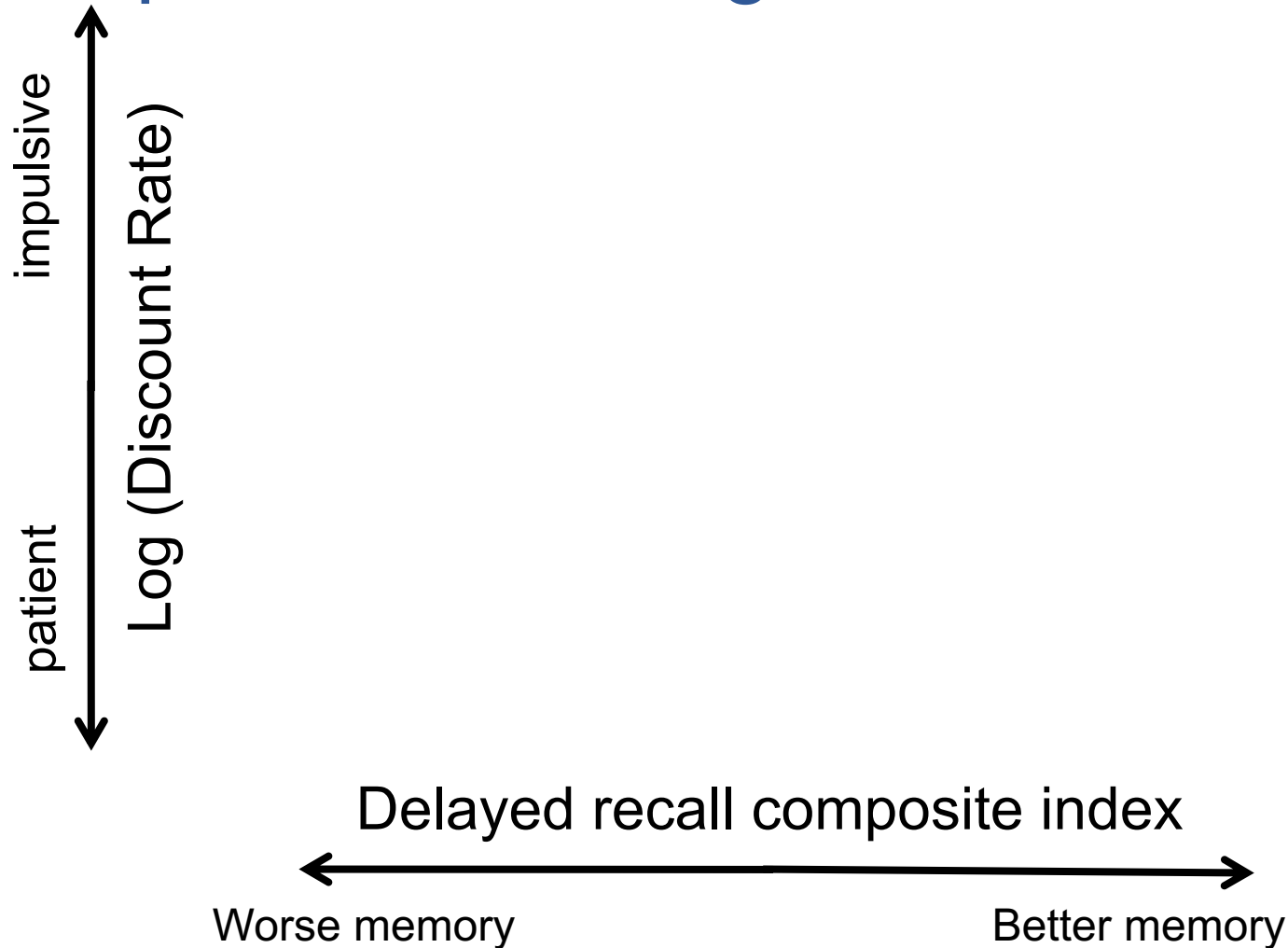
No!

Green = MCI

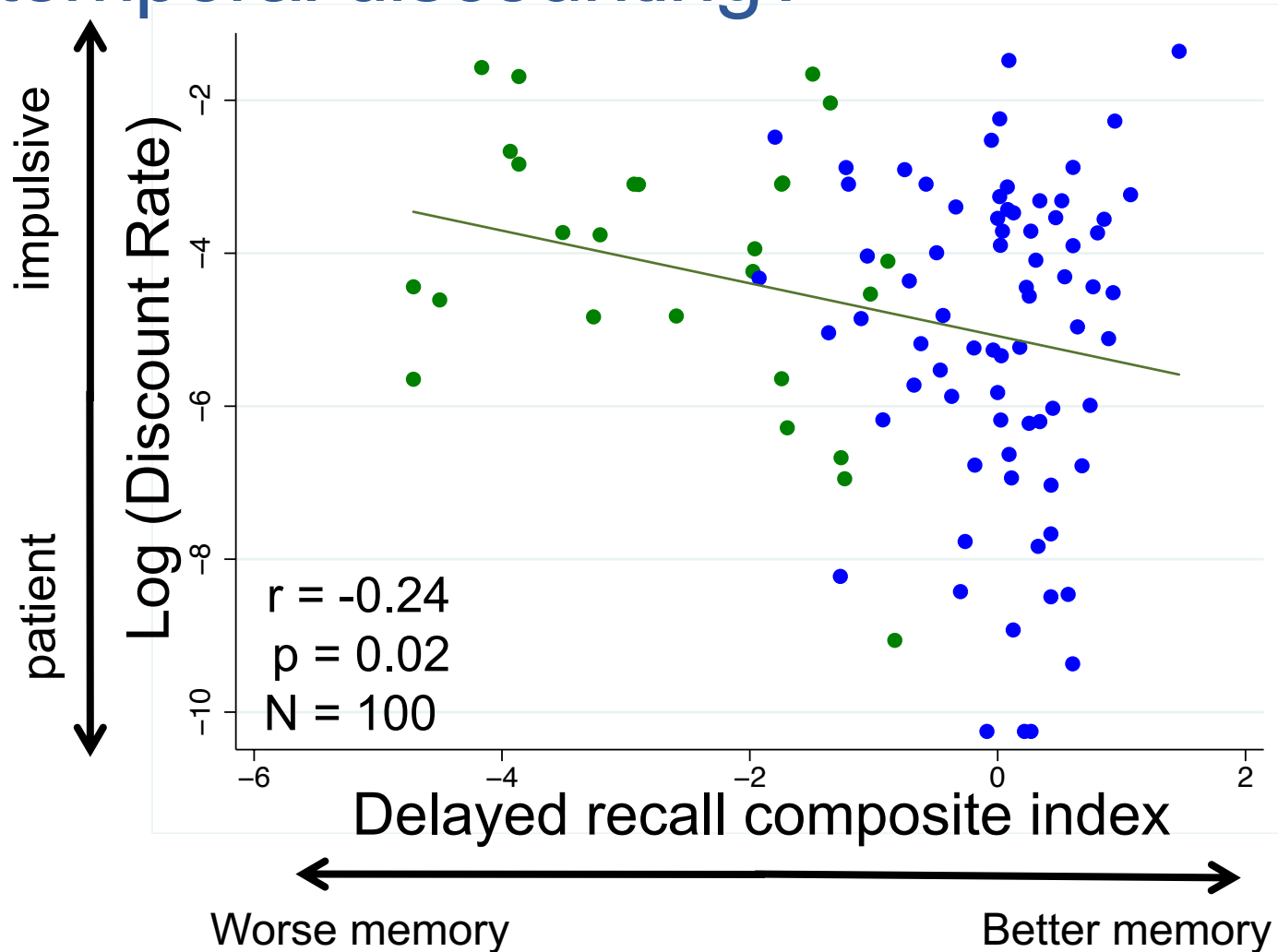
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Does better memory correlate with lower temporal discounting?



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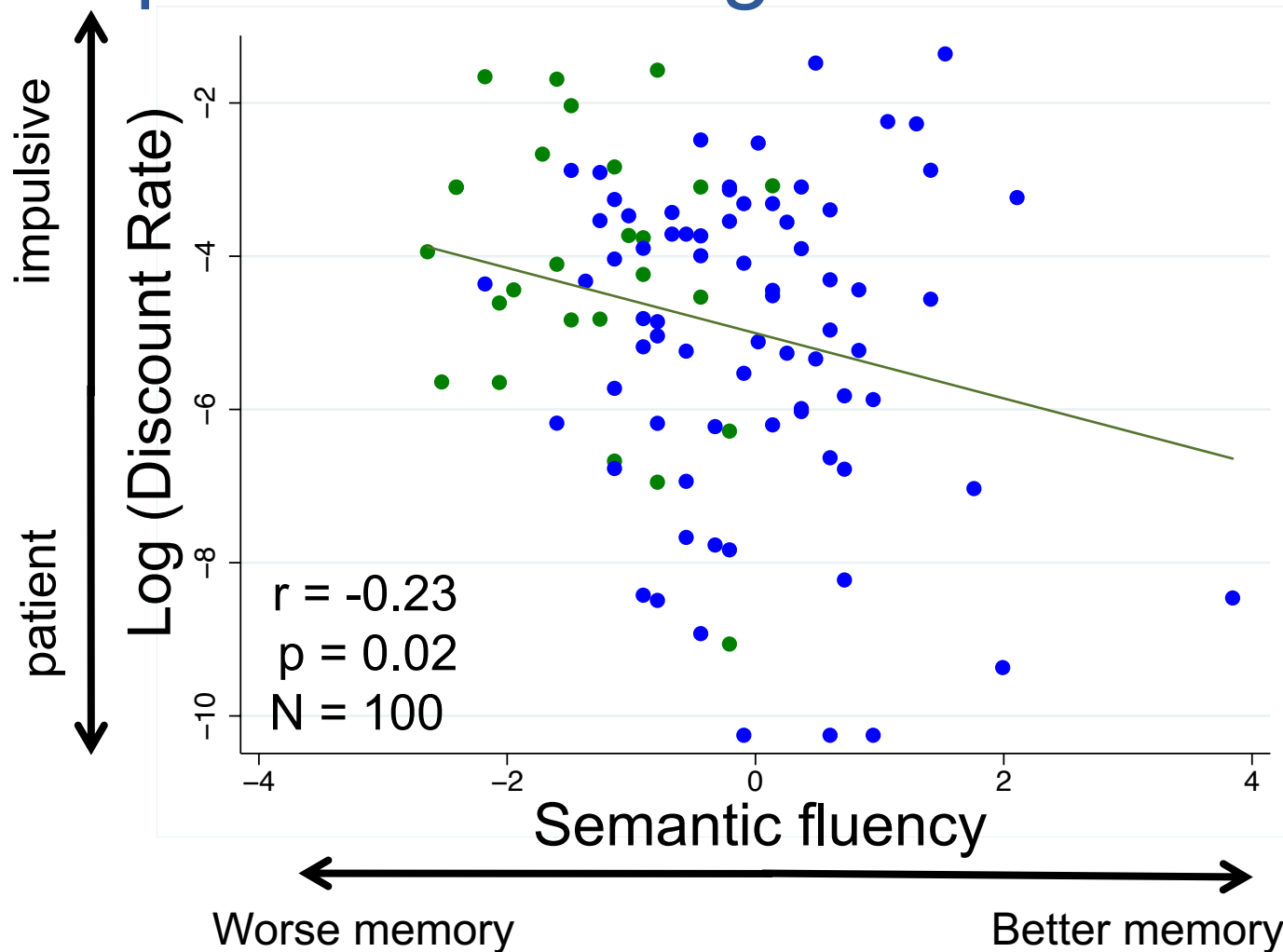
Yes!

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Does better memory correlate with lower temporal discounting?



Yes!

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Individual differences summary

- Declarative memory ability, but not executive function, is associated with temporal discounting in older adults
- Neural measures of episodic memory decline (medial temporal lobe atrophy and white matter lesions related to cerebrovascular disease) are also associated with temporal discounting
- Suggests that we should pursue interventions and manipulations of discount rate that focus on the declarative memory system

Manipulations and interventions

Executive function – based

- Cognitive load during temporal discounting does not influence discount rate (Olschewski et al., 2018; Franco-Watkins et al., 2010)
- Working memory training does not (usually) affect temporal discounting (Kable et al., 2017; Snider et al., 2018, but see Bickel et al., 2011)

Declarative memory - based

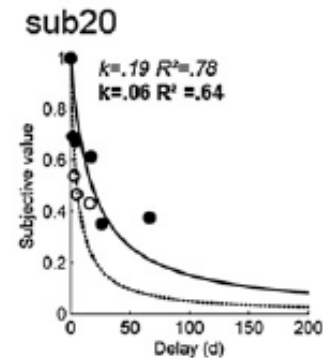
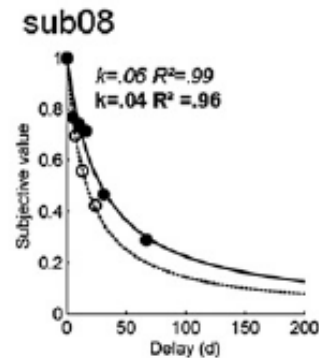
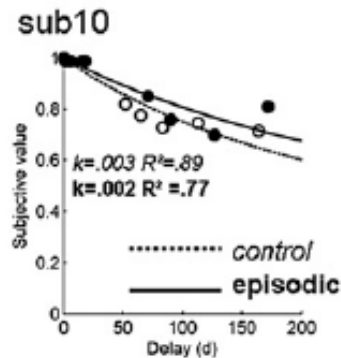
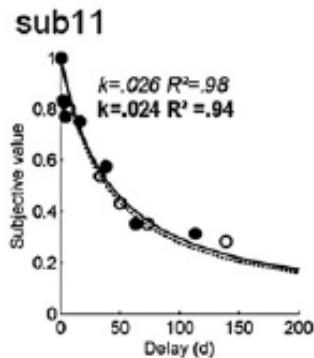
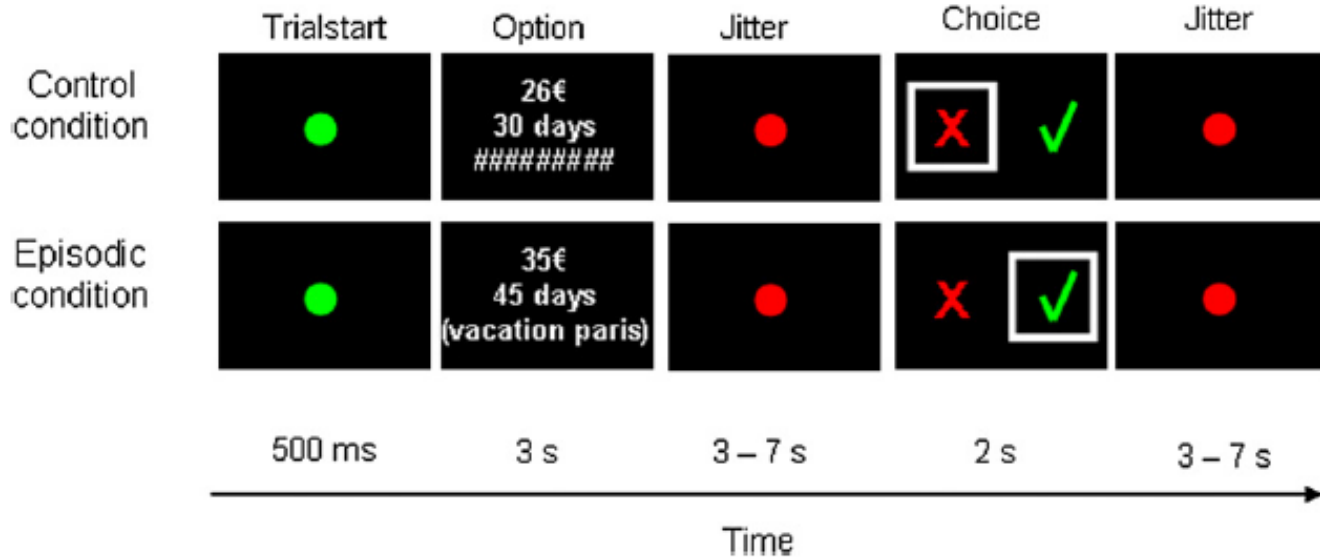
- Positive episodic future thinking (Peters & Buchel, 2010; Benoit et al., 2011; Stein et al., 2016, 2018; Palombo et al., 2015; Bromberg et al., 2017; Sasse et al., 2015; Dassen et al., 2016; Daniel et al., 2015, 2013; Lin & Epstein, 2014; Liu et al., 2013; for review: Bulley et al., 2016)

(Positive) episodic future thinking

- People come up with events that are **specific, positive and vivid** that they are looking forward to
- Cues describing these events are shown before a set of intertemporal choices
- People tend to be more patient on those choices
- This is especially effective when the future events are at the same time as the delays in the choices...

Episodic cues reduce temporal discounting

Reference option: 20€ immediately (not shown)



Episodic future thinking – questions remain

- What are the mechanisms by which this manipulation works?
- Our hypothesis would be that episodic future thinking decreases discount rate by activating the declarative memory system...

Does recalling positive *memories* prior to choice also reduce temporal discounting?

- If **yes**, that suggests that activating this neural circuitry is sufficient to promote patient choice
- If **no**, that suggests that the content of the thought being future-oriented is important

Two-day within-subjects study (N = 35, aged 18-30)

Day 1 (Positive memory recall from 30 event cues)

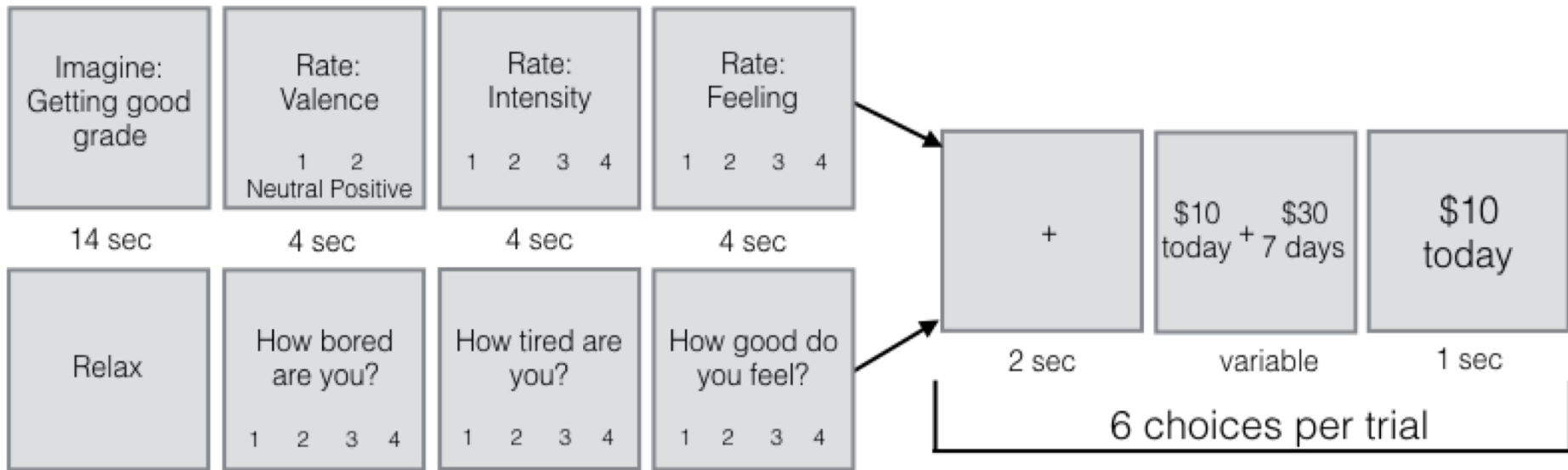
Event cue	Description	Date	Location	Valence	Intensity	Feeling
Graduating	_____	June 2004	My high school	2	3	4
Going to a concert	_____	6/4/16	Central Park	1	2	2
Being in a wedding	_____	2013?	Houston, TX	2	4	4
Favorite team winning championship	_____	2/5/17, Super Bowl	My apt	2	3	3

Day 2 (3 days later)

- 10 positive memories with highest intensity + feeling ratings chosen and summarized in phrases (e.g., “Concert in Central Park”, “Family trip to Cancun”)
- Participants were asked to think about these memories before making intertemporal choices
- **Goal: Compare discount rate (k) in Memory vs. Control conditions.**
- **Prediction: Memory discount rate will be lower than Control discount rate.**

Task layout

Memory condition

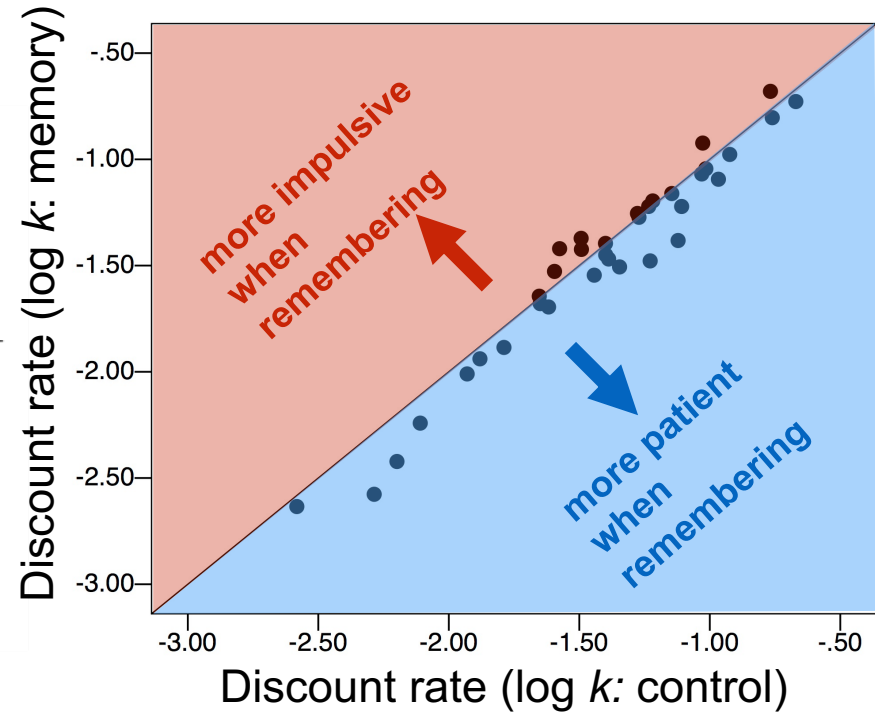
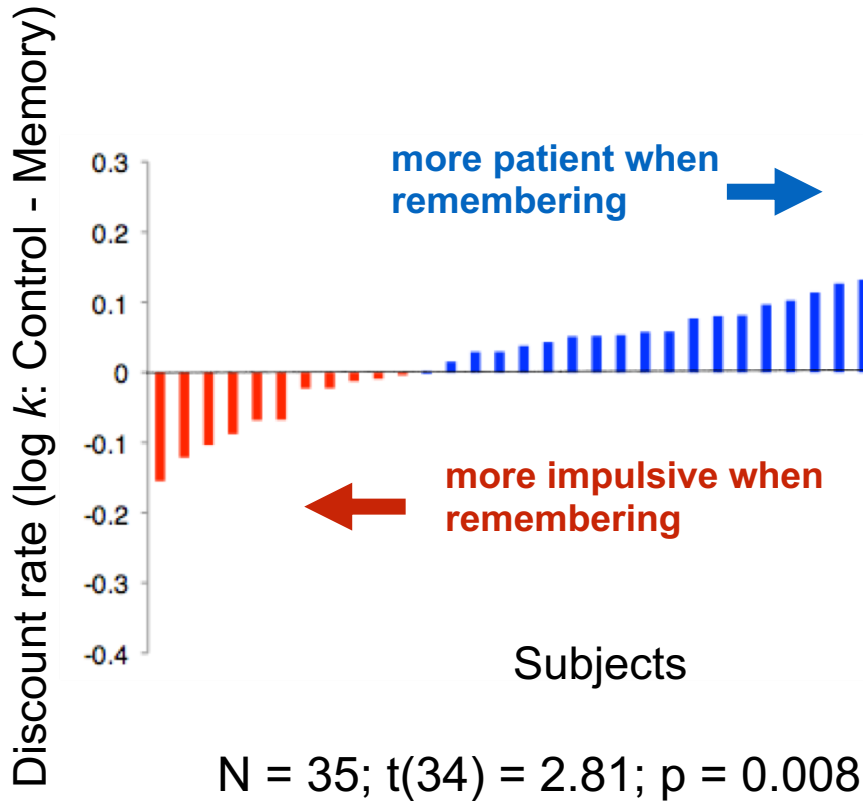


Control condition

10 memories total, 5 memories in a row in each block

10 control blocks total, 5 control trials in a row in each block

Recalling positive memories reduces temporal discounting



Positive memory recall can reduce discounting in young adults

- Positive affect is crucial, since negative memory recall had no effect
- The memory aspect is also important, since positive novel imagery actually made people more impulsive
- Effect size decreased with subsequent replications (Cohen's $d = 0.24$), and we were unable to replicate under certain conditions:
 - with personal photographs used as cues
 - when people were asked to take different perspectives in their memory recollections; and describe their memories verbally
 - on Amazon's Mechanical Turk

Future directions: Incidental effects

- The role of affect, and affective manipulations (e.g., stress, positive mood, gratitude)
- Individual differences in susceptibility to effects (older adults: [Sasse et al., 2017](#); [Lempert et al., in prep](#); rate-dependence: [Snider et al., 2018](#))
- Translating to the real-world and to clinical populations ([Daniel et al., 2015](#); [O'Neill et al., 2016](#); [Snider et al., 2016](#); [Stein et al., 2016](#)), determining generality across domains and tasks
- Developing long-term *training* interventions based on prospection/memory ([Parthasarathi et al., 2017](#))

Conclusions

- While temporal discounting rates are quite stable over time, intertemporal choices can become more patient or more impulsive under certain conditions
- **Framing effects** can be powerful: people tend to choose their “default” option more often, and defaults can be explicit or implicit
- **Incidental effects** that rely on changing the state or strategy of the individual can also change choices, especially if people engage in positive episodic future thinking, but more work is needed to strengthen these interventions and come up with long-term solutions

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- Lapses in self-regulation may stem from people *undervaluing the future*
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Thank you!
Any questions?

