

Investigating Delayed Reward Discounting and its Neural Correlates as Predictors of Smoking Cessation Outcomes

Michael Amlung^{1,2}; Tegan Hargreaves², Carly McIntyre-Wood², Joshua Gray³, Max Owens⁴, James MacKillop², Lawrence Sweet⁵

1. Cofrin Logan Center for Addictions Research, University of Kansas; 2. Peter Boris Centre for Addictions Research, McMaster University; 3. Medical and Clinical Psychology, Uniformed Services University of the Health Sciences; 4. Department of Psychiatry, University of Vermont; 5. Department of Psychology, University of Georgia;

BACKGROUND

Delayed reward discounting (DRD) measures preferences for smaller-immediate vs. larger-delayed rewards. Steeper DRD is an index of impulsivity, with a recent systematic review indicating steeper DRD consistently predicts smoking relapse (Syan et al. 2021).

Neuroimaging studies have characterized the neural correlates of DRD in a range of addiction samples, including cigarette smokers (MacKillop et al. 2012). Less is known about how the neural correlates of DRD relate to smoking cessation. Studying these processes may reveal novel mechanisms and improve prediction of relapse.

Purpose of this study: This study used a functional MRI (fMRI) DRD task to investigate behavioral and neural correlates of relapse in adult smokers following a 9-week cessation protocol.

METHODS

Participants

- 41 smokers (32% female, M age = 40.5, M cigarettes/day = 22.2, M FTND = 4.9) who were motivated to quit (≥ 5 on a 10-point scale)
- Exclusions:** Smoking cessation treatment in past 90 days; major medical or psychiatric disorder; >6 alcoholic drinks/day; >weekly cannabis use or >monthly other drug use; MRI contraindications; estimated IQ <70

Behavioral Task and fMRI Scanning

- Monetary DRD fMRI paradigm (Figure 1) (Amlung et al. 2012)
- 120 DRD trials coded by choice difficulty (i.e., hard vs. easy choices based on proximity to indifference points)
- DRD rate quantified using area under the curve (AUC)
- 1.5-hour fMRI scan in a GE 3-Tesla MRI scanner including 3 runs of DRD task, anatomical scan, resting state, and other neurocognitive tasks
- fMRI data analyzed using disjunction (OR) mask approach and Group (2) x Choice Type (3) mixed ANOVAs

Smoking Cessation Protocol

- Following the fMRI scan, participants completed a free 9-week smoking cessation protocol combining nicotine replacement therapy and weekly counseling
- Smoking relapse defined as self-reported smoking (≥ 1 cigarette/day for 1 week), expired CO >10ppm, or dropping out of the treatment protocol

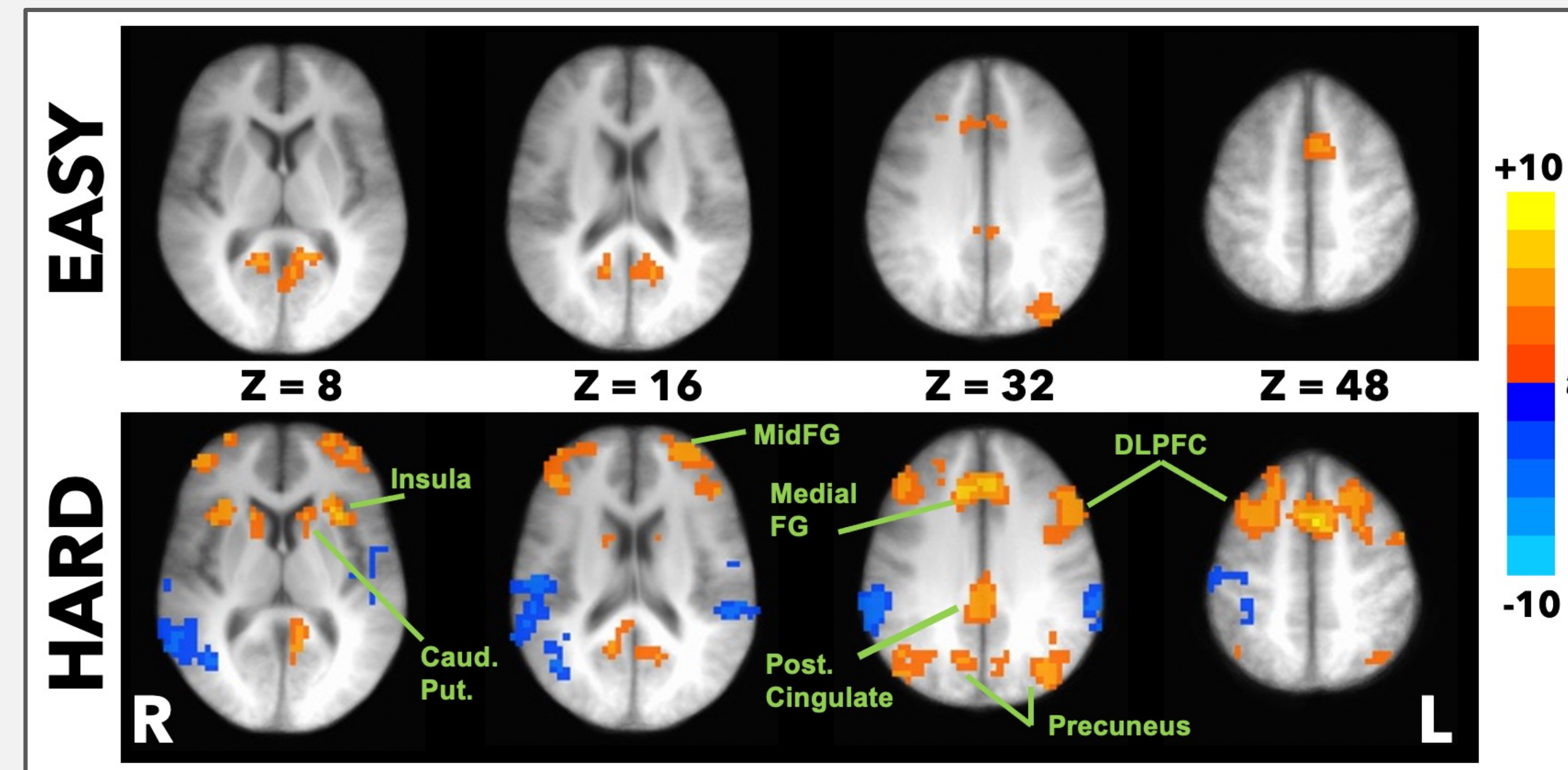


Figure 3. fMRI BOLD Activation during DRD Choices
Group-level activation maps across all participants for easy and hard DRD choices. Both maps reflect results of within-subjects contrast with control trials. $P < .001$, minimum 15 voxels.

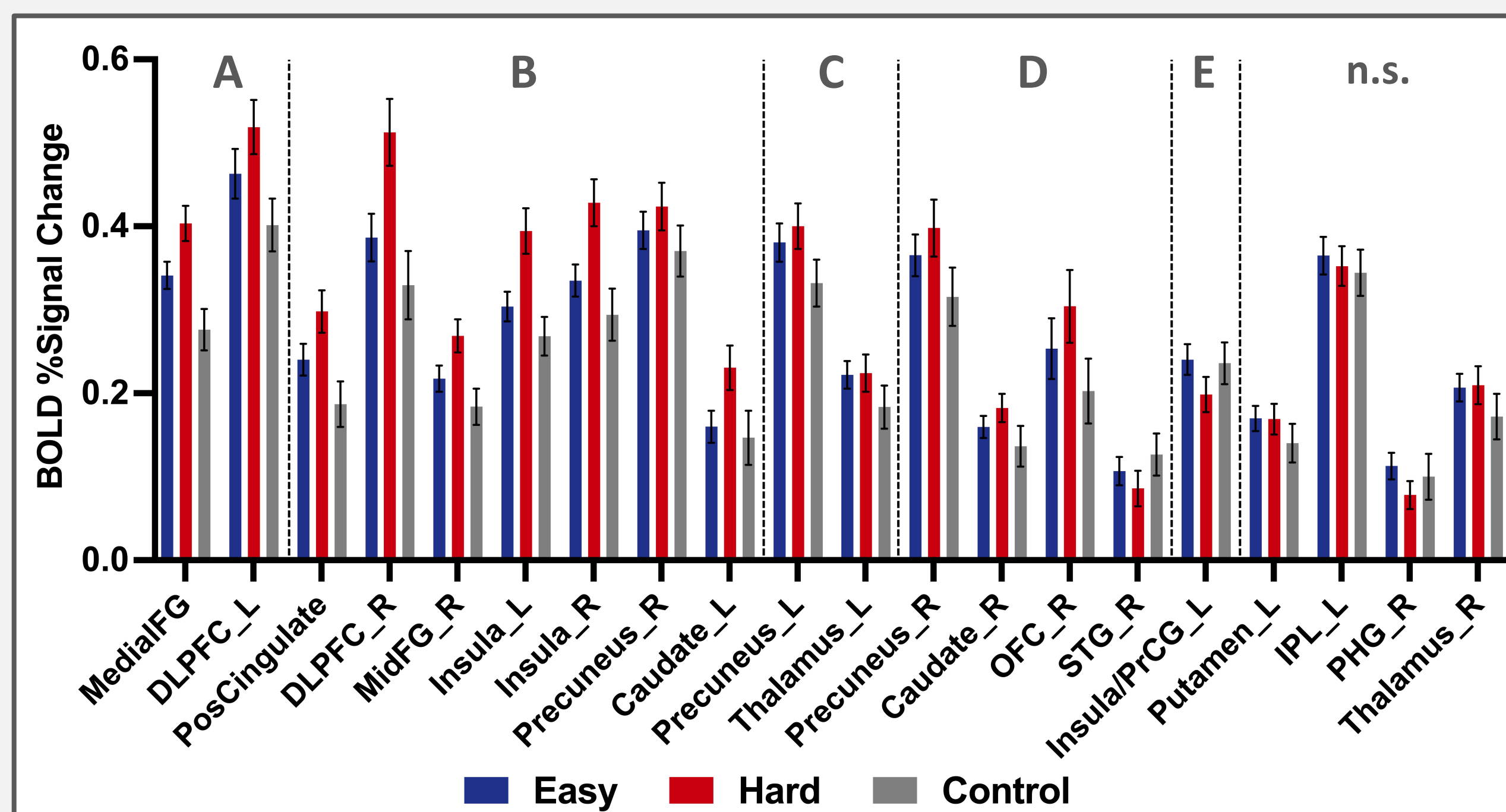


Figure 4. Activation by DRD Choice Type

Results of main effect of choice type for all participants. Bars reflect $M(SE)$.
Pairwise sig. $p < .05$:
A: Hard > Easy > Con
B: Hard > Easy = Con
C: Hard = Easy > Con
D: Hard > Con only
E: Easy > Hard only
n.s.: Non-significant
Abbreviations Table 1

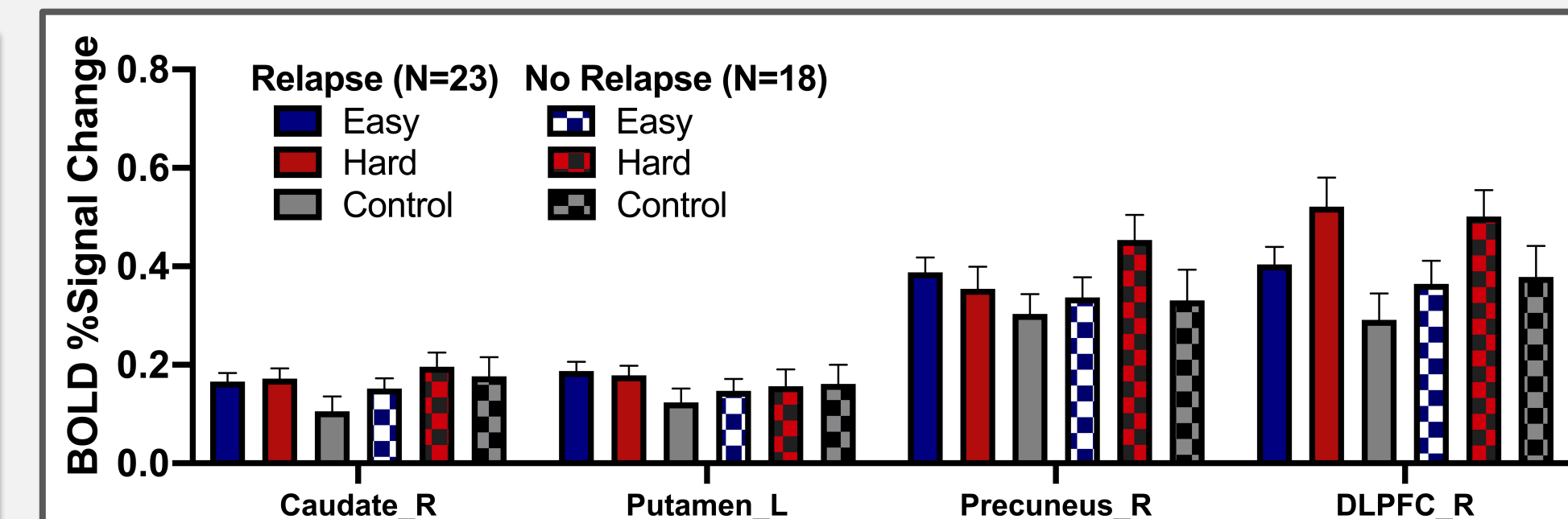


Figure 4. Group x Choice Interactions
Bars reflect $M(SE)$. See Table 1

Table 1. Empirically-defined Regions of Interest

Region (Left/Right) Listed Descending by Size	ME Choice p	ME Group p	Choice x Group p
Medial frontal gyrus [Medial FG]	<0.001	0.436	0.122
Thalamus (L)	0.032	0.340	0.231
Thalamus (R)	0.122	0.211	0.136
Precuneus (R)	0.012	0.289	0.233
Dorsolateral [DLPCF] (L)	<0.001	0.380	0.244
Caudate (R)	0.033	0.419	0.036
Posterior cingulate	<0.001	0.366	0.487
Putamen (L)	0.162	0.815	0.030
Inferior parietal lobule [IPL] (L)	0.597	0.969	0.119
Precuneus (L)	0.002	0.388	0.134
Anterior insula (L)	<0.001	0.589	0.270
Anterior insula (R)	<0.001	0.662	0.168
Precuneus (R)	0.006	0.659	0.019
Parahippocampal gyrus [PHG] (R)	0.378	0.395	0.475
Caudate (L)	<0.001	0.322	0.067
Insula / precentral gyrus [PrCG] (L)	0.017	0.851	0.118
Dorsolateral PFC [DLPCF] (R)	<0.001	0.893	0.043
Middle frontal gyrus [MidFG] (R)	<0.001	0.133	0.203
Oritofrontal cortex [OFC] (R)	0.029	0.195	0.381
Superior temporal gyrus [STG] (R)	0.028	0.463	0.238

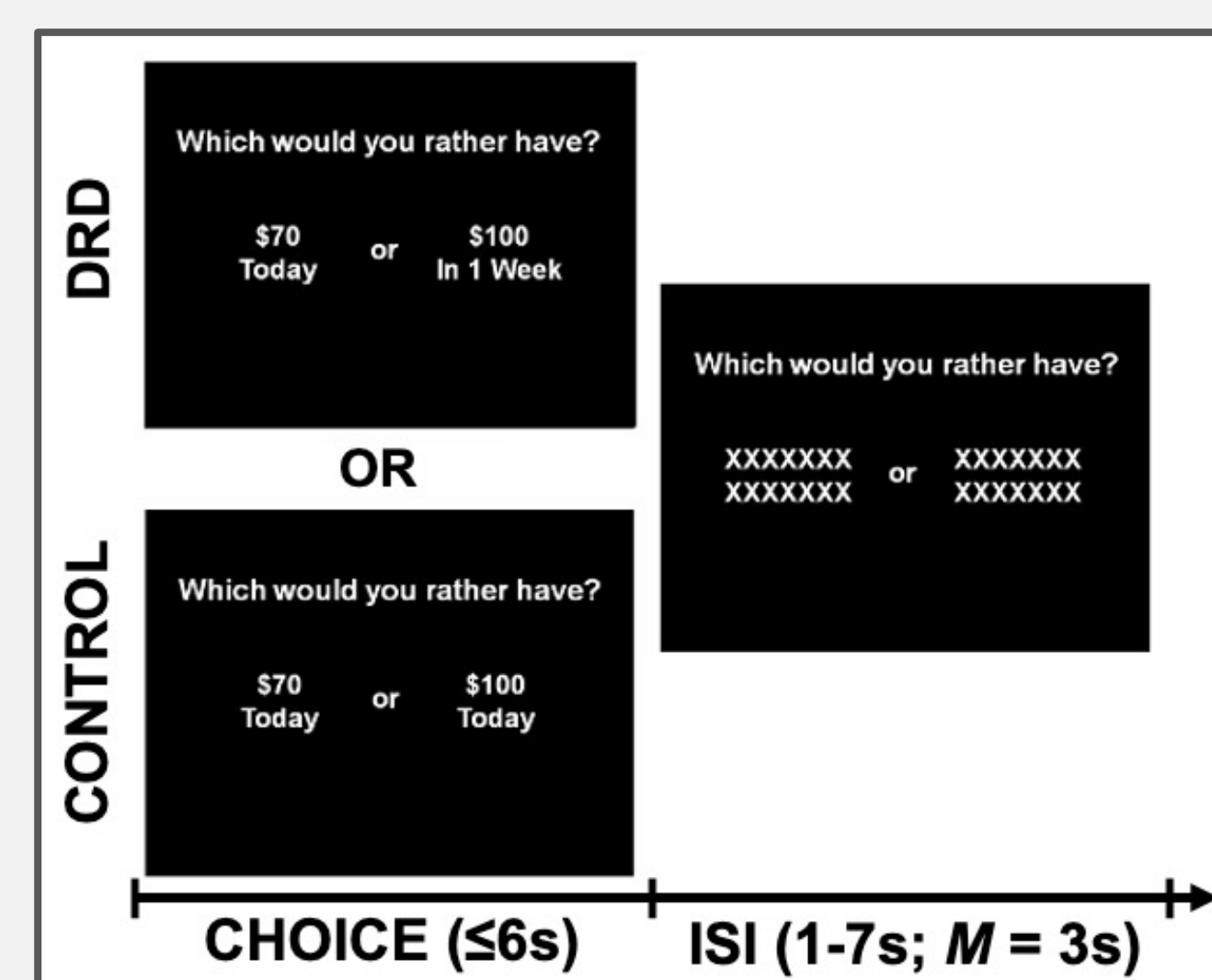


Figure 1. fMRI DRD Paradigm
DRD choices involved choices for \$100 after 1 day-1 year delay and \$10-99 immediately. Control choices involved two immediate rewards. ISI = interstimulus interval

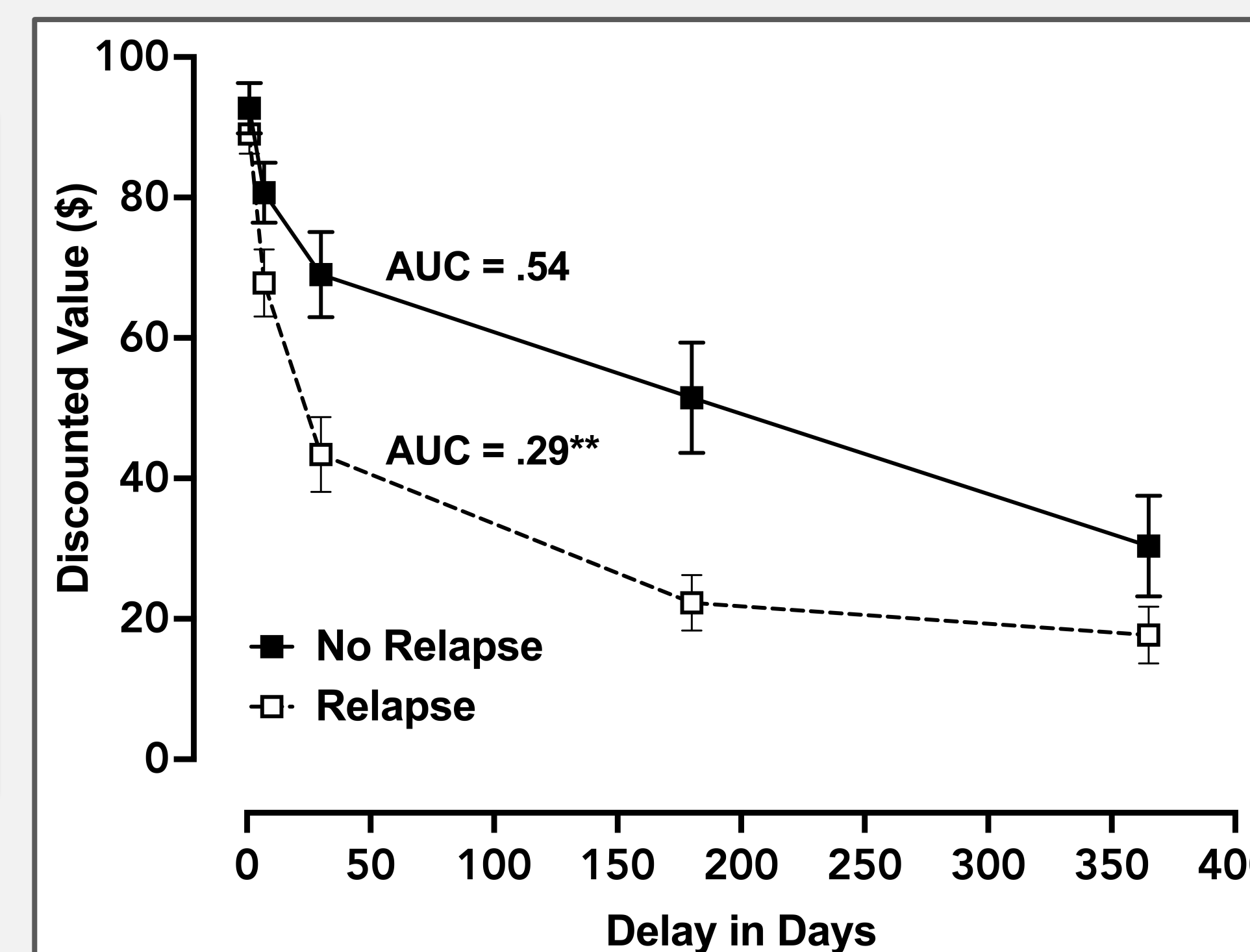


Figure 2. Steeper DRD in Smoking Relapse Group
Discounting curves for relapse ($n=23$) and no relapse ($n=18$) groups. Data points reflect $M(SE)$ indifference points at each delay. AUC = area under curve; ** $p < .01$

CONCLUSIONS

These results further characterize the neural correlates of DRD in smokers. Individuals who discounted more steeply were more likely to resume smoking following treatment. Despite limited statistical power, there were promising interaction effects that should be further examined in future studies to inform neural and behavioral models of relapse.