Within-person mismatch of reward responsiveness and executive functioning: A longitudinal validation of the dual systems model from childhood to adulthood

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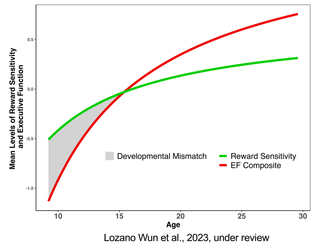
INTRODUCTION

- The dual systems model suggests that the developmental mismatch between reward and executive systems in adolescence contributes to increased tendencies to engage in risk-taking behaviors[1,2].



Lozano Wun et al., 2023, under review

- Mismatches between reward and executive systems in late adolescence are associated with higher levels of heavy episodic drinking in emerging adulthood[3] and concurrently with deviant behavior from adolescence to early adulthood[4].
- Extant research provides some evidence of sex differences in traits such as sensation seeking[5,6], reward sensitivity[7], and impulsivity[6,8], as well as rates and types of alcohol use[9].
- Longitudinal examinations of directly quantified differences between these systems and their associations with substance use are necessary[10].

Aim: Using an accelerated longitudinal design of individuals aged 9-30 years assessed biennially up to five times, explore concurrent associations with directly quantified differences between reward responsiveness and executive function (EF) and alcohol use from late childhood to early adulthood, including potential effects of biological sex.

SAMPLE

Unique Individuals	N=188
Total Alcohol Frequency Observations	N=584
Total Alcohol Quantity Observations	N=614
Baseline Age: range	9.2 - 24.0
Baseline Age: mean (SD)	16.4 (4.1)
Total Age: range	9.2 – 29.6
Total Age: mean (SD)	19.2 (4.6)
Female %	57.7%
White %	87.8%
Maternal Years of Education: mean (SD)	15.64 (2.2)
SD=standard deviation. Age presented in years	

METHODS

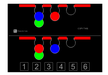
MEASURES

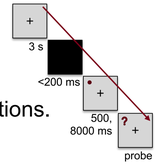
Reward Responsiveness

Behavioral Inhibition System/Behavioral Activation System Scale[11] – BAS Reward Responsiveness subscale

EF Composite

- CANTAB Stockings of Cambridge: total percent correct[12]
- CANTAB Spatial Working Memory test[12]
  - Total Between (i.e., forgetting) Errors for trials with 6 and 8 boxes
  - Average strategy score for trials with 6 and 8 boxes
- WISC-III Digit Span Backward: length of last span correct[13]
- Spatial Delayed Response Task: efficiency score (error x RT on 8s delay trials)[14-15]





All measures were standardized using baseline distributions. EF composites were created by averaging Z-scores of collected measures.

Within-person difference = $Z_{Reward} - Z_{EF}$

Alcohol Use in the Past 12 Months:

- Determined from Personal Experience Inventory (PEI)[16] and Kiddie Schedule for Affective Disorders and Schizophrenia (KSADS)[17]
- Frequency of consumption
- Average quantity consumed per drinking session

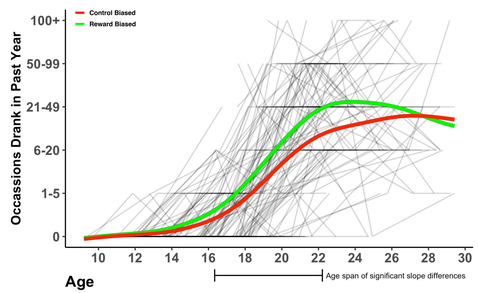
ANALYSIS

- Generalized Additive Mixture Modeling (GAMM) for frequency and quantity using restricted maximum likelihood (REML) and random effect of individual[18]
- Corrected conditional AIC for model comparison[18]
- Parsed interaction effects with difference score by testing 0 ± 1 SD, correcting for FDR[19]
- Parsed interaction effect with sex correcting for FDR[19]

AIC Comparisons		
Model	Frequency	Quantity
s(age)	1720.90	2073.07
s(age) + s(difference)	1718.22	1957.16
s(age, difference)	**1716.65**	1957.36
s(age, difference) + s(sex)	1717.81	1956.57
s(age, difference) + s(age, sex)	1718.05	**1945.78**
s(age, difference) + s(difference, sex)	1722.45	1950.03
Bold font indicates best-fitting model for each outcome		

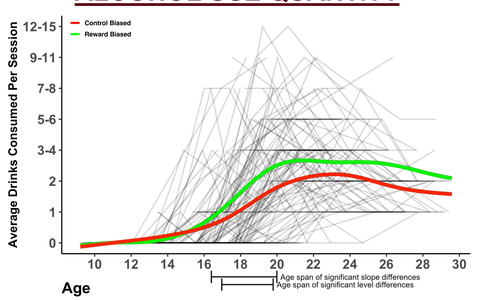
RESULTS

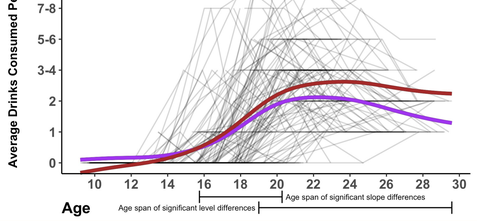
ALCOHOL USE FREQUENCY



Best-Fitting Model Results		
Outcome	Frequency	Quantity
Age x Diff Spline (edf | *p-value*)	12.7 | p<.001	13.59 | p<.001
Age x Sex Spline (edf | *p-value*)	-	1.55 | p=<.001
Random Intercept Spline (*p-value*)	p = .21	p < .001
Deviance Explained (%)	56.5%	62.9%

ALCOHOL USE QUANTITY





CONCLUSION

- Overall, developmental mismatches between reward and executive systems were significantly associated with how often and how much individuals drank alcohol, such that greater reward biases were associated with greater alcohol consumption frequency and quantity.
- The associations between developmental mismatches and alcohol use varied with age. Reward-biased individuals increased their frequency and quantity of alcohol use at a greater rate than control-biased individuals during mid-to-late adolescence, and reward-biased individuals consumed more alcohol than control-biased individuals during late adolescence only.
- Associations between the mismatch of reward and executive systems and alcohol use did not appear to vary significantly by biological sex.
- However, developmental changes in the quantity of alcohol used varied with biological sex. Specifically, during mid-to-late adolescence, males increased how much alcohol they consumed at a faster rate than females, and by late adolescence and into early adulthood, males consumed larger quantities of alcohol when compared to females.
- Taken together, mid-to-late adolescence appears to be a period where reward-biased individuals are at particular risk for increased alcohol use, providing support for the dual systems model of adolescent development.

Citations: [1]Casey et al., 2008 [2]Steinberg, 2008 [3]McCabe et al., 2021 [4]Vazsonyi & Ksinan, 2017 [5]Cross et al., 2012 [6]Shulman et al., 2015 [7]Schreuders et al., 2018 [8]Cross et al., 2011 [9]White, 2020 [10]Meisel et al., 2019 [11]Carver & White, 1994 [12]Owen et al., 1990 [13]Wechsler, 1991 [14]Luciana et al., 1998 [15]Luciana & Collins, 1997 [16]Winters & Henly, 1989 [17]Kaufam et al., 2010 [18]mgcv: Wood et al., 2016 [19]emmeans: Russell et al., 2023

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