Supplemental material for

"Daily caffeinated soda intake is associated with impaired working memory and higher impulsivity in children"

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We examined differences in all measures between the four groups (non-drinking, weekly-drinking, monthly-drinking, daily-drinking) using an analysis of variance (ANOVA), and made post-hoc pairwise comparisons using Tukey's test. The main objective was to test whether the three soda-drinking groups (monthly-drinking, weekly-drinking, daily-drinking groups) differed significantly from the non-drinking group.

ANOVA revealed a significant main effect of group on soda intake per week ($F(3, 3962)=1161$, $p<0.001$), and all demographic factors, including family income ($F(3, 3962)=46.06$, $p<0.001$), parental education ($F(3, 3962)=51.50$, $p<0.001$), parental monitoring ($F(3, 3962)=7.88$, $p<0.001$), BMI ($F(3, 3962)=19.37$, $p<0.001$), physical activity ($F(3, 3962)=11.47$, $p<0.001$), amount of sleep ($F(3, 3962)=33.19$, $p<0.001$), externalizing behaviors ($F(3, 3962)=7.74$, $p<0.001$), and internalizing behaviors ($F(3, 3962)=3.31$, $p=0.019$).

There was a main effect of groups for all behavioral measures of WM (List Sorting Test: $F(3, 3962)=14.16$, $p<0.001$; Card Sort Test: $F(3, 3962)=5.68$, $p<0.001$; [EN-Back] 2-back: $F(3, 3962)=3.74$, $p=0.011$; [EN-Back] 0-back: $F(3, 3962)=5.60$, $p<0.001$), and except for the left amygdala ($F(3, 3962)=4.69$, $p<0.001$), there was no main effect for all neural data (R hippocampus: $F(3, 3962)=1.46$, $p=0.224$; L hippocampus: $F(3, 3962)=1.08$, $p=0.356$; R amygdala: $F(3, 3962)=2.56$, $p=0.054$; R DLPFC: $F(3, 3962)=0.16$, $p=0.923$; L DLPFC: $F(3, 3962)=0.14$, $p=0.936$). There was a significant main effect on all behavioral measures of impulsivity except for the SSRT (SSRT: $F(3, 3962)=1.70$, $p=0.165$; UPPS-P: $F(3, 3962)=12.62$, $p<0.001$; BIS: $F(3, 3962)=10.67$, $p<0.001$; BAS: $F(3, 3962)=16.67$, $p<0.001$), and there was no main effect on any neural data (R caudal ACC: $F(3, 3962)=0.58$, $p=0.631$; L caudal ACC: $F(3, 3962)=0.81$, $p=0.489$; R IFG: $F(3, 3962)=0.53$, $p=0.661$; L IFG: $F(3, 3962)=2.12$, $p=0.095$). In the reward processing measures, a main effect of groups was found for all neural data except for activity in the right NAc (L PCC: $F(3, 3962)=6.77$, $p<0.001$; R PCC: $F(3, 3962)=5.79$, $p<0.001$; L NAc: $F(3, 3962)=3.21$, $p=0.022$; R NAc: $F(3, 3962)=0.72$, $p=0.539$), and there was no main effect on behavioral data ([MID] difference in hit rates between reward vs. neutral trials: $F(3, 3962)=2.34$, $p=0.072$; [MID] difference in hit rates between loss vs. neutral trials: $F(3, 3962)=1.99$, $p=0.113$).

Table S1 shows the post-hoc pairwise comparison results of demographic factors among the four groups (non-drinking, monthly-drinking, weekly-drinking, daily-drinking). Several demographic factors were significantly different between the four groups. Higher caffeinated soda intake was associated with a lower SES (parental income & parental education), lower parental monitoring, higher BMI, lower amount of physical activity, and less sleep. Low WM (lower performance in the List Sorting Test, Card Sort Test, and EN-Back Task), high impulsivity (higher score in the UPPS-P and BIS/BAS), and indifference toward monetary rewards (smaller difference in performance between the reward vs. neutral trials and loss vs. neutral trials) were found in the daily-drinking group compared to the non-drinking group. This supports the idea that daily consumption of caffeinated soda might be a risk factor and a predictor of future substance misuse. Among the ROIs, hyperactivation of the amygdala was found in the daily-drinking group (compared with the non-drinking group) during the EN-Back Task.

Table S1.

Baseline characteristics of participants

variable	Non-drinking (0 can)	Monthly-drinking (< 1 can /week)	Weekly-drinking (< 7 can / week)	Daily-drinking (≥ 7 can / week)
Sample size	1640	1721	464	141
Soda intake / week	0	0.46 (0.01)***	2.86 (0.06)***	14.92 (1.32)***
demographic variables				
Women, No. (%)	917 (0.56)	820 (0.48)	173 (0.37)	66 (0.47)
Age	9.5 (0.01)	9.55 (0.01)**	9.64 (0.02)***	9.49 (0.04)
Family income	8.06 (0.04)	7.8 (0.05)***	7.07 (0.11)***	6.65 (0.21)***
Parental education	17.4 (0.05)	16.9 (0.06)***	16.19 (0.11)***	15.83 (0.22)***
Parental monitoring	4.47 (0.01)	4.44 (0.01)	4.37 (0.02)***	4.35 (0.05)*
Family history (drug)	0.29 (0.01)	0.3 (0.01)	0.36 (0.02)*	0.34 (0.04)
Family history (alcohol)	0.43 (0.01)	0.48 (0.01)**	0.46 (0.02)	0.42 (0.04)
BMI	17.9 (0.09)	18.5 (0.09)***	19.11 (0.2)***	19.6 (0.45)***
Physical activity	4.20 (0.06)	3.94 (0.06)*	3.52 (0.11)***	3.44 (0.20)**
Amount of sleep	1.50 (0.02)	1.61 (0.02)***	1.81 (0.04)***	1.93 (0.08)***
Externalizing behaviors	44.01 (0.23)	44.12 (0.23)	46.14 (0.48)***	45.93 (0.91)
Internalizing behaviors	44.61 (0.26)	44.10 (0.25)*	45.84 (0.51)	46.62 (0.93)
Working memory				
Behavioral measures				
List Sorting Test	104.61 (0.34)	103.54 (0.33)	101.59 (0.63)***	97.91 (1.34)***
Card Sort Test	99.88 (0.38)	99.39 (0.37)	95.64 (1.23)*	95.57 (1.15)**
[EN-Back] (2-back)	0.81 (0.002)	0.80 (0.002)	0.80 (0.004)	0.79 (0.007)*
[EN-Back] (0-back)	0.88 (0.002)	0.88 (0.002)	0.87 (0.004)	0.85 (0.008)***
fMRI data				
[EN-Back] Right hippocampus	-0.07 (0.005)	-0.07 (0.005)	-0.06 (0.01)	-0.047 (0.02)
[EN-Back] Left hippocampus	-0.079 (0.005)	-0.082 (0.005)	-0.07 (0.01)	-0.057 (0.018)
[EN-Back] Right DLPFC	0.062 (0.006)	0.059 (0.006)	0.064 (0.012)	0.051 (0.021)
[EN-Back] Left DLPFC	0.042 (0.005)	0.04 (0.006)	0.044 (0.012)	0.031 (0.02)
[EN-Back] Right amygdala	-0.071 (0.007)	-0.075 (0.007)	0.043 (0.014)	-0.026 (0.029)
[EN-Back] Left amygdala	-0.066 (0.006)	-0.075 (0.006)	-0.044 (0.012)	-0.003 (0.024)*
Impulsivity				
Behavioral measures				
UPPS-P	39.70 (0.18)	40.82 (0.18)***	41.56 (0.37)***	41.94 (0.63)**
BIS	24.86 (0.19)	25.80 (0.18)**	26.48 (0.36)***	27.55 (0.68)***
BAS	19.58 (0.16)	20.54 (0.16)***	21.35 (0.31)***	22.53 (0.58)***
[SST] SSRT	299.51 (1.62)	302.29 (1.55)	297.27 (2.87)	308.76 (5.59)
fMRI data				
[SST] Right caudal ACC	0.068 (0.003)	0.073 (0.003)	0.072 (0.007)	0.062 (0.012)
[SST] Left caudal ACC	0.062 (0.003)	0.068 (0.003)	0.07 (0.007)	0.061(0.01)
[SST] Right IFG	0.103 (0.004)	0.109 (0.004)	0.101 (0.007)	0.104 (0.014)
[SST] Left IFG	0.057 (0.003)	0.069 (0.003)*	0.058 (0.006)	0.059 (0.013)
Reward processing				
Behavioral measures				
Cash Choice Task	1.61 (0.01)	1.59 (0.01)	1.61 (0.02)	1.60 (0.04)
[MID] earned money	21.23 (0.30)	22.14 (0.29)*	21.983(0.58)	22.34 (1.11)
[MID] reward vs. neutral	0.12 (0.003)	0.11 (0.003)	0.106 (0.006)	0.09 (0.01)*

[MID] loss vs. neutral	0.095 (0.003)	0.093 (0.003)	0.083 (0.006)	0.071(0.012)*
fMRI data				
[MID] Right PCC	0.024 (0.004)	-8.7e-05 (0.004)***	0.006 (0.008)*	0.004 (0.015)
[MID] Left PCC	0.014 (0.004)	-0.011 (0.004)***	-0.005 (0.008)*	-0.013 (0.014)
[MID] Right nucleus accumbens	0.060 (0.005)	0.05 (0.005)	0.057 (0.01)	0.063 (0.02)
[MID] Left nucleus accumbens	0.082 (0.005)	0.063 (0.005)	0.050 (0.02)	0.044 (0.017)

Note. Data are Mean (Standard Error): *: $p < 0.05$, **: $p < 0.01$; ***: $p < 0.001$ (each soda drinking groups (monthly-drinking, weekly-drinking, daily-drinking) compared with the non-drinking group)
Abbreviations. BMI, Body Mass Index; EN-Back, Emotional N-Back Task; DLPFC, Dorsal Lateral Prefrontal Cortex; SST, Stop Signal Task; ACC, Anterior Cingulate Cortex; IFG, Inferior Frontal Gyrus; MID, Monetary Incentive Delay Task; [MID] reward vs. neutral, difference in percentage of correct trials between reward trial and neutral trial; [MID] loss vs. neutral, difference in percentage of correct trials between loss trial and neutral trial; PCC, Posterior Cingulate Cortex.