

Luteal phase is associated with blunted nucleus accumbens activity during real-time fMRI neurofeedback in adolescents and young adults

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Introduction: The luteal phase of the menstrual cycle has been linked to altered reward responding, but menstrual cycle phase is frequently overlooked in neuroimaging research. This is problematic because hormonally linked variation may obscure individual and developmental differences in reward-circuit function, particularly among females during adolescence, when reward circuitry is still maturing and vulnerability to affective disorders increases. The nucleus accumbens (NAcc) is a key reward-region implicated in motivation, reinforcement learning, and affective regulation. Real-time fMRI neurofeedback offers a promising approach for assessing volitional modulation of NAcc activity; however, whether luteal phase status is associated with NAcc regulation during neurofeedback remains unclear. The present study examined associations between luteal phase status and NAcc activity during real-time fMRI neurofeedback in adolescents and young adults.

Methods: Fifty-seven healthy female participants completed a single-session real-time fMRI neurofeedback task targeting up- and down-regulation of NAcc activity. The sample included adolescents ages 14–16 years, $n = 31$, and young adults ages 25–27 years, $n = 26$; 59.5% of participants identified as White. Participants were categorized as being in the luteal phase or non-luteal phase based on self-reported menstrual cycle timing at the scan, with luteal phase defined as approximately 14 days after menstrual cycle onset. The neurofeedback task consisted of four runs: Run 1, feedback off; Run 2, feedback on; Run 3, feedback on; and Run 4, feedback off. Each run included 12 pseudorandomly ordered increase and decrease trials. Primary outcomes were NAcc percent signal change during increase and decrease trials, compared by luteal phase status across and within developmental groups.

Results: Across both age groups, NAcc percent signal change during Run 2 decrease trials was significantly lower among participants in the luteal phase compared with those in the non-luteal phase, respectively, $M = -0.02$, $SD = 0.12$ vs. $M = 0.05$, $SD = 0.14$, $p < .05$. Developmental group analyses indicated additional phase-related differences. Among adolescents, participants in the luteal phase showed lower NAcc percent signal change compared with non-luteal participants during Run 3 increase trials, $M = 0.03$, $SD = 0.11$ vs. $M = 0.08$, $SD = 0.12$, $p < .05$, and Run 4 decrease trials, $M = -0.03$, $SD = 0.11$ vs. $M = 0.00$, $SD = 0.21$, $p < .05$. Among young adults, luteal phase participants showed lower NAcc percent signal change compared with non-luteal participants during Run 1 decrease trials, $M = 0.01$, $SD = 0.09$ vs. $M = 0.04$, $SD = 0.09$, $p < .05$.

Conclusions: These findings suggest that luteal phase status is associated with blunted NAcc signal change during real-time fMRI neurofeedback, supporting links between menstrual cycle phase and reward-related neural responding. Results further suggest that these associations may differ between adolescents and young adults, although the observed developmental patterns require replication. Given the modest sample size and single-session design, larger and more comprehensive studies are needed to characterize menstrual cycle effects on reward-circuit self-regulation and to determine how real-time fMRI neurofeedback may be used to assess hormonally linked variability in neural function across development.