

Adolescent Attention to Emotion Study

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Background: Rates of depression increase rapidly during adolescence, especially for girls, and, thus, research is needed to spur the development of novel interventions to prevent adolescent depression. This project sought to determine if a novel visuocortical probe of affect-biased attention (i.e., steady-state visual evoked potentials derived from EEG) could be used to modify affect-biased attention and buffer subsequent mood reactivity. This work could ultimately directly inform the development of mechanistic treatment targets to be used in personalized intervention prescriptions for high-risk youth.

Objectives: This study explored the feasibility of implementing SSVEP neurofeedback training to reduce stimulus-driven attention to negative distractors, enhance goal-directed attention, and buffer mood reactivity in response to a discrete laboratory stressor.

Outcomes:

Primary outcome: To measure change from baseline in affect-biased attention subsequently following neurofeedback.

To measure affect-biased attention, steady-state visual evoked potentials (SSVEPs) were derived from EEG and used to index the amount of stimulus-driven attention to the negative distractors relative to goal-directed attention toward task-relevant stimuli. Larger SSVEPs indicate more attention to that stimulus. Affect-biased attention was measured both before and after the real time SSVEP neurofeedback training to assess changes in affect-biased attention pre- to post-intervention. Competition indices for attention to the primary task vs negative emotional distractors at both baseline and post-intervention were calculated by dividing T-transformed SSVEP amplitudes to the task stimuli by the sum of the T-transformed amplitudes to the distractor and task stimuli. Scores above .50 reflect greater attention to the task whereas scores below .50 reflect greater attention to the distractor.

Secondary outcome 1: To measure change from baseline in sadness after a laboratory stressor, which follows neurofeedback.

Participants completed a laboratory stressor following real time SSVEP neurofeedback training to assess how well it buffered sadness reactivity. To assess sadness reactivity, girls reported state sadness before and after the stressor using Visual Analog Scales. Participants marked how they were feeling between neutral to very sad on a scale measuring 100 millimeters, with higher scores indicating greater state sadness.

Secondary outcome 2: To measure change from baseline in anxiety after a laboratory stressor, which follows neurofeedback.

Participants completed a laboratory stressor following real time SSVEP neurofeedback training to assess how well it buffered anxiety reactivity. To assess anxiety reactivity, girls reported state anxiety before and after the stressor using Visual Analog Scales. Participants marked how they are feeling between neutral to very anxious on a scale measuring 100 millimeters, with higher scores indicating greater state anxiety.

Study Design:

Design Type: Single-arm pilot study

Participants: Participants included 15 female adolescents ages 13 years 0 months through 15 years 11 months at study entry.

Exclusion Criteria:

1. Lifetime history of any DSM 5 depressive disorder
2. Lifetime history of taking antidepressants (e.g., SSRIs)
3. Lifetime history of a DSM 5 psychotic, bipolar, or autistic spectrum disorder.
4. Presence of EEG contraindications (e.g., personal lifetime history of seizures or family history of hereditary epilepsy).
5. Being pre-pubertal
6. Lifetime history of a neurological or serious medical condition.
7. Lifetime history of head injury or congenital neurological anomalies (based on parent report).
8. IQ less than 80, as assessed using the Wechsler Abbreviated Scale of Intelligence (WASI).
9. Uncorrected visual disturbance
10. Being acutely suicidal or at risk for harm to self or others.

Recruitment: 15 participants were recruited from the community.

Procedure: Girls completed one session of a task designed to give feedback on performance on an EEG-based task assessing affect-biased attention. Specifically, girls received feedback based on activity from EEG electrode sites that captured how much they were able to reduce attention to the distracting angry or sad emotional face relative to attention to task-relevant stimuli. Girls completed a laboratory stressor following the feedback task where they completed a set of anagrams, some of which were insoluble, and they were told that their performance on the task reflected intelligence. At the end of the task, they received fake negative feedback about their performance relative to peers. Girls reported state sadness and anxiety before and after the stressor using Visual Analog Scales.

Adverse Events: Adverse events were monitored continuously throughout study participation via direct report from participants and study staff observation. No adverse events were observed or reported.

Statistical Analysis Plan (SAP):

Analysis Populations:

- All participants who were enrolled (N = 15).
- Outcome-specific exclusions:
 - VAS sadness and VAS anxiety were missing for one participant at baseline; analyses were conducted on the remaining 14 participants for those measures
 - For post-stressor sadness and anxiety ratings, three participants had missing data; analyses were conducted on the remaining 12 participants
- Analyses were performed on observed data only; no imputation was used for missing data.

Primary Outcome Analysis:

- Outcome: SSVEP competition index (0-1 scale)
- Analysis: Pre- vs post-neurofeedback scores compared using a two-tailed paired samples t-test
- Null hypothesis: No mean difference in competition index from baseline to post-training
- Significance threshold: $p < .05$, two-sided
- Reported results: mean pre vs post scores, standard deviations, and p-value

Secondary Outcome Analysis 1 – VAS Sadness:

- Outcome: Self-reported sadness on a 0–100 Visual Analog Scale (VAS).
- Analysis: Pre- vs post-stressor scores compared using a two-tailed paired samples t-test
- Null hypothesis: No mean difference in sadness ratings from baseline to stressor
- Significance threshold: $p < .05$, two-sided
- Handling of missing data: 3 participants did not provide post-stressor sadness scores; analysis conducted on 12 participants.
- Reported results: mean pre vs post scores, standard deviations, and p-value

Secondary Outcome Analysis 2 – VAS Anxiety:

- Outcome: Self-reported anxiety on a 0–100 Visual Analog Scale (VAS).
- Analysis: Pre- vs post-stressor scores compared using a two-tailed paired samples t-test
- Null hypothesis: No mean difference in anxiety ratings from baseline to stressor
- Significance threshold: $p < .05$, two-sided
- Handling of missing data: 3 participants did not provide post-stressor anxiety scores; analysis conducted on 12 participants.
- Reported results: mean pre vs post scores, standard deviations, and p-value

Additional Considerations

- All tests were exploratory given the pilot nature of the study and small sample size.
- No corrections for multiple comparisons were applied.

- Analyses were performed using paired-sample t-tests only; no regression or correlation analyses were prespecified.

Power Analyses:

Because this was a pilot study, no formal *a priori* power calculations were conducted. The sample size of 15 allowed the study team to test feasibility, acceptability, and to provide preliminary analyses for future larger-scale studies. The results are considered exploratory.

Informed Consent:

All participants' legal guardians provided written informed consent and participants provided written assent. The consent document covered a broader parent study (Attention to Emotion in Adolescents), of which this pilot study was a part of. The study protocol was reviewed and approved by the University of Pittsburgh Institutional Review Board (IRB). All data were de-identified prior to analysis and confidentiality was maintained in accordance with institutional and federal guidelines.

Limitations and Caveats:

Results indicated that SSVEP competition scores decreased significantly from baseline to post-training, suggesting increased attention to emotional distractors and reduced goal task-relevant attention. There were no significant changes in reported sadness or anxiety. One possible explanation for the increase in attention to emotional distractors may be task-related fatigue.

The study had several limitations. First, the sample size was small, and analyses were underpowered to detect significant effects. Second, a single arm design limits causal inference. Third, outcomes were measured within 1 hour of completing neurofeedback and no follow-up assessments were conducted. Finally, the sample consisted only of adolescent girls, which may limit generalizability.