Effects of acute aerobic exercise on ocular measures of emotion processing during an emotional face perception task

C. REYES[1], N. THOM[2], H. THOMAS[3], N. VARBERG[3], M. P. HERRING[4,5], M. J. CAMPBELL[4,5]

1. Wheaton College, Applied Health Science Department, Wheaton, IL. 2. Wheaton College, Biology Department, Wheaton, IL. 3. Wheaton College, Physics Department, Wheaton, IL.
4. University of Limerick, Department of Physical Education and Sport Sciences5. University of Limerick, Health Research Institute, Limerick, Ireland

Background

- Depression and Bipolar disorder are among the leading causes of disability worldwide, with depression projected by the WHO to be the 2nd most disabling condition by 2020
- It is well known that exercise enhances mood, especially in depressed and anxious participants, but mechanisms of exercise-induced mood enhancement are not well understood.
- *Adaptive changes in attentional biases to emotional stimuli could underlie the psychobiological mechanism by which exercise enhances on mood.*
- Attentional bias is a predisposition to preferentially direct attention toward threat-related stimuli rather then positive or neutral stimuli
- Exercise may attenuate attentional biases toward unpleasant emotional images both during and after exercise, and increase attentional bias toward positive emotional images
- Advanced eye-tracking concurrently measures multiple objective physiological markers of direct visual attention and could be used to detect changes in emotional function after exercise

Goal: Use eye-tracking metrics to examine the effects of acute aerobic exercise and/or quiet rest on attentional bias while viewing emotional stimuli

Methods

- Sample: N=35 (18 women) aged 21.1±1.4y
- Protocol: two counterbalanced 30-min conditions: vigorous running or seated rest. Eye-tracking occurred pre- and 20-min post-condition.
- Data: Corneal reflection was measured using a Tobii x 120 while viewing 45 photographs from NimStim depicting positive (n=15), neutral (n=15), and negative (n=15) facial expressions.
- Images were displayed for 2000 ms followed by a fixation cross to aid in re-centering of gaze
- Defined mouth and eye regions were used to determine attention to or avoidance of salient emotional information

(Image courtesy of Open-i NLM)

Fig 1: Examples of NimStim images. The mouth and eyes provide salient emotional information in social interactions. Tobii software allows for defining of "target" regions—here the mouth and eyes. The number of fixations in these areas was compared against each target area as well as against fixations outside any target areas

- Associated development of novel software products for calculating number of fixations, scan path length, fixation duration, and longest fixation from gaze point data as well as for analysis of AOI hits and percent of AOI hits in individual and combined regions

Fig 2: Novel GUI-based MATLAB software was developed to calculate all parameters from structured data output by Tobii software. Each function above was programmed by the authors and allowed for comprehensive analysis of physiological parameters beyond any commercially available software

Results

Gaze Pattern Analysis

- Significant interaction effects between time and emotional content were found for fixation durations and longest fixation
  - Fixation duration was significantly longer for positive compared to neutral images at pre-condition (time X emotion ($F(2,64)=3.21$, $p<0.05$), mean difference=50.64, $p\leq0.004$) and non-significantly longer compared to negative images at post-condition (mean difference=37.06, $p>0.08$) (Fig. 4).
  - Compared to neutral images, positive images resulted in a significantly longer longest fixation at pre-condition (time X emotion ($F(2,64)=3.12$, $p\leq0.05$),mean difference=57.04, $p\leq0.004$) (see Figure 7)
- These interaction effects were likely driven by the main effect of emotional content for both indices of attention (fixation duratio, p=0.04; longest fixation, p=0.05) (see Figures 5 & 8)

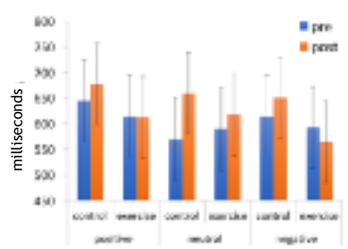

Fig 3: Fixation duration, all data

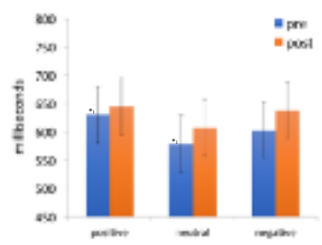

Fig 4: Fixation duration was significantly longer for positive compared to neutral images at pre-condition (time X emotion) and non-significantly longer compared to negative images at post-condition.

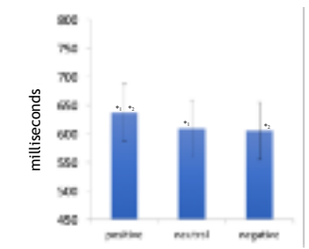

Fig 5: Fixation duration was significantly longer for positive compared to neutral and negative images ($p=0.005$ and 0.056, respectively). Fixation durations between neutral and negative images were not significantly different ($p=0.816$)

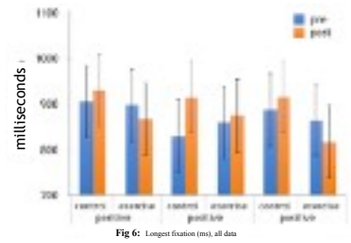

Fig 6: Longest fixation (ms), all data

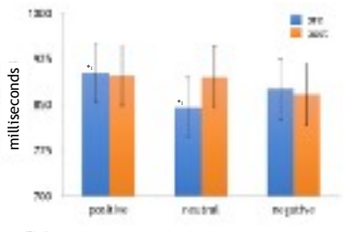

Fig 7: Longest fixation duration was significantly longer for positive compared to neutral ($p\geq0.05$). Acute exercise did not significantly alter longest fixation duration (all $p>0.05$).

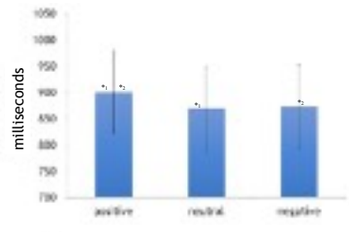

Fig 8: Duration of longest fixation was significantly longer for positive compared to both negative and neutral images.

AOI Analysis

- Emotional content of the images significantly effected which AOI was preferentially fixated on
  - For the left eye, %fixations was significantly higher for negative images compared to both positive ($M_{diff}=0.02$, $p<0.001$) and neutral ($M_{diff}=0.05$, $p<0.001$), and significantly higher for positive compared to neutral ($M_{diff}=0.03$, $p<0.001$) (See Figure 9).
  - For the right eye, %fixations was significantly higher for positive compared to both negative ($M_{diff}=0.03$, $p<0.001$) and neutral ($M_{diff}=0.01$, $p\leq0.008$), and significantly lower for negative images compared to neutral ($M_{diff}=-0.02$, $p<0.001$) (See Figure 10).
  - Across all AOIs, %fixations was significantly higher for both positive and negative images compared to neutral ($M_{diff}=0.02$, $p<0.001$ and $M_{diff}=0.01$, $p<0.001$) (See Figure 11).
- There was also a significant effect of time
  - Regardless of emotional content, the percent fixations on all AOIs was greater post-condition ($F_{(1,34)}=5.40$, $p<0.03$) *(results not pictured here)*

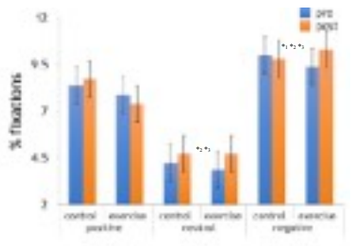

Fig 9: Percent fixations, left eye

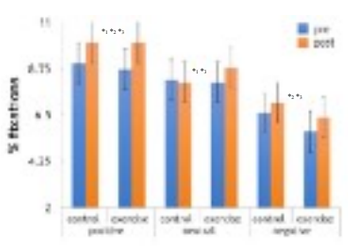

Fig 10: Percent fixations, right eye

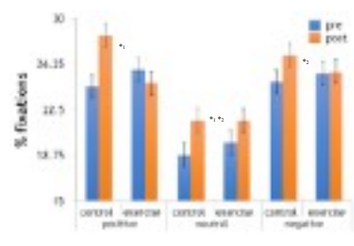

Fig 11: Percent fixations, all AOI. Compared to neutral images, the percent of fixations was significantly higher for both positive ($M_{diff}=0.02$, $p<0.001$) and negative images ($M_{diff}=0.01$, $p<0.001$). Positive and negative images did not significantly differ ($p>0.11$). Averaged across condition and emotion, the percent of fixations was also significantly higher post-intervention ($M_{diff}=-0.01$, $p<0.03$)

Discussion

Eye-tracking effectively detected different emotional processing patterns and scanning strategies while viewing emotional stimuli. However, acute exercise did not significantly alter emotional response as indexed by fixation duration, number of fixations, longest fixation, or AOI preference. In the model we postulated by which emotional response could mediate the effects of exercise on mood, we would have expected to see participants have significant positive changes in their emotional processing patterns post-exercise compared to pre-condition. This would include increased fixation (both frequency and duration) on positive stimuli and decreased fixation on negative stimuli. Though AOI fixation is more complex and the implications of positive effects can change based on conditions like anxiety or trait anger, we would generally expect post-exercise to see higher percent fixations on the AOIs for positive images and decreased percent fixations in AOIs for negative images.

Instead we found that emotional response post-exercise did not differ significantly from either pre-condition or from post-rest. However, this was clearly not due to insufficiency of methods of data collection and analysis. Different emotional content of images also correlated with different scanning patterns and fixation tendencies. This can be seen in participants' tendency to fixate more frequently on positive images at all times. However, it is especially evident in the analysis of which AOI participants fixated on most frequently for each category of emotional content. Interestingly, the pattern of fixations on the eyes is nearly inverted from negative to positive images—possibly an indicator to part of the differential viewing strategies for positive and negative emotional content. However, averaged across all AOIs, participants spent significantly more time looking at the eyes and mouth for positive and negative images than they did for neutral images, and this did not change post-condition. This indicates that while viewing an image for the same amount of time, participants spent significantly more time gathering salient emotional information from the eyes and mouth for positive and negative images than they did for neutral images.

In conclusion, though our results do not rule out a mechanism by which altered emotional response mediates positive changes in mood post-exercise, it does not provide sufficient evidence to support this model. However, we have learned that regardless of whether the participants exercised or rested, post-condition they viewed the same images differently, and pictures with different emotional content elicited different processing patterns. Intervention does have a significant effect on parameters of emotional response, even though the changes produced by exercise are not significantly different than those seen after quiet rest.

Conclusions:

- **Though exercise did not have a significant effect on gaze patterns, eye-tracking did effectively detect significant differences of emotional response across multiple metrics**
- **Detection of different emotional content is evidenced in significant differences in pre-condition fixation preferences as well as the significantly higher percent of fixations within AOIs for negative and positive images compared to neutral**
- **Both exercise and quiet rest produced changes in gaze patterns, with participants displaying increased scan path length as well as more frequent fixations within AOIs post-condition**