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Exercise-Induced Enhancement of Focus and Calm

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Can exercise change the way we engage with the world? Many have noted the link between exercise and affect. Studies have demonstrated exercise-induced increases in neurochemicals such as dopamine, serotonin, and norepinephrine (Lin & Kuo, 2013); these neurochemicals are often associated with affective improvements (Salgado-Pineda, P., Delaveau, P., Blin, O., & Nieoullon, A., 2005). Exercise has also been linked to improvements in the areas of concentration (Silva, Prado, Scardovelli, Boschi, Campos, & Frère, 2015; Budde, Voelcker-Rehag, Pietrabyk-Kendziorra, Ribeiro, & Tidow, 2008), memory (Stroth, Hille, Spitzer, and Reinhardt, 2009), cognition (Tomporowski, 2003), emotion regulation (Bernstein & McNally, 2018) and executive control (Hillman, Snook, & Jerome, 2003). In a previous study, we found that a 20- minute round of exercise improved participant scores in the self-reported areas of mood, focus, and wakefulness (Davis, 2022). This was especially compelling when compared with sedentary peers, who reported drops in those same areas after 20 minutes of sitting.

Theoretically, if a low-cost intervention like exercise can improve affect, then there would be reason to consider incorporating it in all sorts of arenas – namely, schools and businesses. Improvements in mood would surely allow students and employees to interact with their peers and work differently, and (hopefully) achieve enhanced outcomes.

Improvements in wearable technologies like the brain-sensing FocusCalm headband have allowed us to continue this research with greater depth. During late summer and fall of 2021, we attempted to replicate those previous studies – this time, instead of collecting self-reports, the FocusCalm technology allowed us to collect electroencephalogram (EEG) feedback.

Field Research Methods

Measurement. Previous studies using the Good Athlete Project exercise intervention have relied on self reported feedback. This design aims to measure the impact of an exercise routine on brain functioning to confirm positive results on mood and participant affect. To do this, we used the BrainCo FocusCalm wearable EEG monitor. The electroencephalogram (EEG) is a device used to measure electrical signals in the brain at different points in time. Electrodes, small discs of metal, are placed on the scalp to detect these signals. A signal occurs during the excitation of a neuron, creating the electrical potential recognized by the device. Neurons, or brain cells, are the basic working units of the brain (Holmes & Khazipov, 2007). They become excited by a stimulus from inside or outside the body that evokes a physical or psychological response (Saeid & Chambers, 2007). When this happens, neurons create electrical impulses, and assemblies of neurons behave as electrical generators that produce EEG signals measured on the scalp.

A large population of active neurons can generate enough potential to be measurable by the electrodes on the scalp and gives a view of neural activity. It can be used to unobtrusively study brain activities.

The recorded electrical activity from the brain occurs at different frequencies, measured in Hertz (Hz), resulting in different frequency bands in the EEG signal. These brainwave frequency bands can be classified into delta, theta, alpha, beta, and gamma. Using algorithms expressed as ratios of EEG frequency bands, changes in attention-related neural activity can be understood. Multiple experiments have validated this approach as a reliable way to measure attention-related features (Kramer, 1991; Klimesch et al, 1998; Sauseng et al, 2005; Gola et al, 2013).

Although these simple algorithms might lack the specificity of machine learning based approaches that take into account the device and exact task being done, they can act as a foundation for refinement. Prinzel et al. used the now well-known “engagement index” to measure the changes in cognitive engagement in subjects while they completed resource management tasks (Prinzel et al, 2001). A tracking task was switched between manual and automatic task modes and an auditory oddball monitoring task. The engagement index compares the power of the beta (13-20Hz) frequency band to the sum of the theta (4- 8Hz) and alpha (8-12Hz)

frequency bands which can be expressed as: (beta/theta+alpha). Preset frequency bands like this one are also used in analyzing EEG outcome measures, such as examining the differences between people with and without ADHD (Heinrich et al., 2014).

BrainCo uses a more data-driven approach to quantify the state of a user, rather than the frequency band approach described above. A neural network model takes raw EEG signals as inputs to the model, which generates over 1000 features per EEG data window that customize and update the output every second based on the individual's unique EEG activity. This neural network model is used in the analysis of cognitive workload and relaxation level in this study. More recently, machine learning techniques are being applied to generate more specific and accurate algorithms. Some of these work by using classification models to predict the cognitive state of the subject. They are developed by asking subjects to do tasks associated with cognitive workload and relaxation, then creating a model to predict the likelihood that a subject is in one of these states based on the EEG features detected.

Experiment. Twenty (20) participants were recruited to participate in our study. The exercise routine we selected was part of an educational intervention designed by the nonprofit organization Good Athlete Project. The 20-minute intervention is broken into four phases:
Eight minutes (8:00) target cardio; (2:00) strength; (8:00) maintenance cardio; (2:00) balance.

8:00 Target Cardio	2:00 Strength	8:00 Maintain Cardio	2:00 Balance
Select ability-appropriate cardio option; RPE 7-8	Ability-appropriate resistance training option; RPE 7-8	Select cardio option to maintain exertion level, do not exceed RPE 8	Pre-selected balance routine, multiple planes of motion

The Exercise Effect, Anchor Routine; Good Athlete Project

During the initial eight minute (8:00) ‘target cardio’ phase, participants selected a method of cardiovascular exercise appropriate to their existing fitness level: running, jogging, biking, or elliptical training. Participants were instructed to work toward an exertion level that would be challenging, but not exhausting; we kept this front of mind by asking participants to maintain a level of exertion measuring 7-8 on a 10 point scale. RPE is shorthand for “rate of perceived exertion”, a term the participants were familiar with, made famous by Swedish researcher Gunnar Borg (Borg, 1982). Borg’s exertion scales have been widely used to measure physiological intensity of participants in a variety of studies. As a measure of physical and psychological strain, exertion scales have proven to be sufficiently reliable and prove especially valuable when equipment is limited (Lamb, et al, 1999). After the initial target cardio phase, participants enter the two minute (2:00) strength phase. During the strength phase, participants perform thirty second (:30) bouts of Bodyweight Squats, Pushups, Side Lunges, and Burpees under the supervision of a Certified Strength & Conditioning Specialist, using the guidelines outlined in the National Strength and Conditioning Association’s Guide to High School Strength and Conditioning, Chapter Five, Bodyweight Training (Davis, 2021). All participants were familiar with the technique required to perform these movements and did not require guidance.

The third phase, ‘maintenance cardio’, lasted another eight minutes (8:00). During this second cardio phase, participants select a method of cardiovascular exercise which will allow them to maintain their exertion level without crossing over into a state of exhaustion. “Get into a groove and try to hold it for the next eight minutes,” we said. Eleven participants (n=11, 55% of total participants) changed their choice of equipment. The most common change was from treadmill to elliptical. Very little instruction was needed for this phase.

The ‘balance’ phase lasted for two minutes (2:00). The balance exercise used in the study is referred to as Ankle Prehab. Participants stand on one leg and touch the toe of that leg with their opposite arm, then return to their initial position (e.g. Stand on the left leg, hinge at the waist and touch left toes with the right hand, return to standing position). Participants switched feet and hands every thirty seconds (:30).

Through these four phases, the participants were kept at a medium-high

level of exertion (RPE 7-8), without crossing over into exhaustion (9 or above would be too strenuous), for twenty continuous minutes. These parameters were selected for three reasons: 1) studies have shown positive results in as few as twenty minutes (Hillman et al, 2009), 2) twenty minutes should be logistically compatible with one standard school period or workday, and 3) over-exertion could have deleterious effects (Tomporowski, 2003). This routine has been used in schools across the country, but EEG measurements were not used to validate those results. To measure the effect of the exercise routine, we asked participants to engage with one of the brain games on the FocusCalm platform. We selected the Stroop Test for its straightforward directions and its use in other, similar studies (Scarpina & Targini, 2017). The Stroop test is a well known test of executive functioning wherein the participant's attention is guided between the written word and the color of that word. The participant is directed to select the color of the text as it appears on screen. When the word appears in blue text, the participant taps a button for 'blue'. When the word appears in red text, the participant taps a button for 'red'. When there is a mismatch (for example, the word "red" appears in blue text), executive functioning is required to avoid tapping the 'red' button and instead tap the 'blue' button to identify the color of the text. The two primary areas in the brain that are involved in this process are the anterior cingulate cortex, and the dorsolateral prefrontal cortex (Pardo et al, 1990; Taylor, 1997). Participants took the Stroop test before and after the exercise routine.

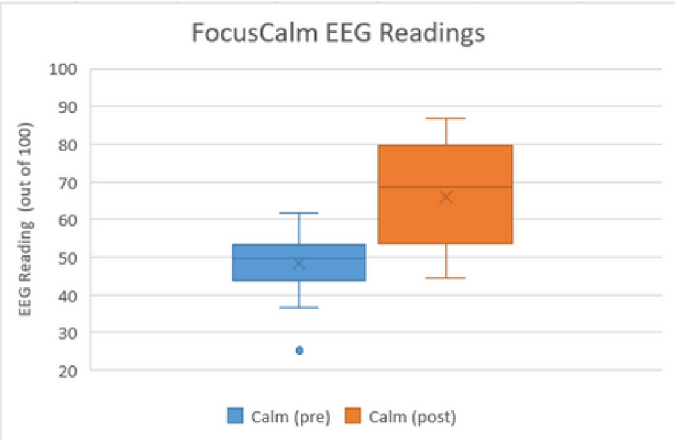
We compared the Stroop test scores on the test before and after, but that was not really what we were after; in fact, one could suggest that the score is irrelevant, as the participant might have just improved with practice. However, while the participant took the test, the FocusCalm headband was collecting data. Specifically, we were interested in the FocusCalm score, which is a proprietary measure based on relative state of both focus and calm, as measured through EEG readings. Theoretically, improvements in focus and calm should decrease stress. Previous studies with FocusCalm have shown an 18% increase in wellbeing, 21% reduction in burnout, and 13% reduction in anxiety [FocusCalm in Workplace Wellbeing, 2021: https://focuscalm.com/pages/workplace#whitepaper].

Results & Discussion

We recognize that this is field research, which is not held to the same rigor

as peer-reviewed, IRB approved research. That said, our findings have given us a great opportunity to reflect on our practice, improve the culture of organizations with whom we work, and lead us toward further studies.

During the experiment, Stroop test scores stayed relatively consistent, which was anticipated and, as mentioned, not the focus of our study. The only reason those scores were tracked was to ensure that the challenge of exercise did not inhibit performance on the test. It did not. The EEG score is what we were interested in, and it produced the most compelling result.



After a 20-minute round of exercise, the FocusCalm scores rose from an average of 48.29 (±8.87) to 65.87 (±13.40) on a 100 point scale. This accounts for an impressive 37.91% increase. A t-test was performed to confirm statistical significance ($p<0.001$). Based on the results of previous studies, we were expecting a positive result, but this was more than we could have anticipated. If a 20-minute round of exercise can improve focus and calm by nearly 40%, it seems that it could be included in a variety of positive interventions. In schools, businesses, or in one's daily life, who would not want to feel increased focus and calm?

These results should be considered along with the additional positive effects of regular exercise: improved cardiovascular health (Pinckard, Baskin, & Stanford, 2019), decreases in risk for many preventable diseases (Lao, et al, 2018), and a likely increase in self efficacy (Tikac, Unal, & Atug, 2022).

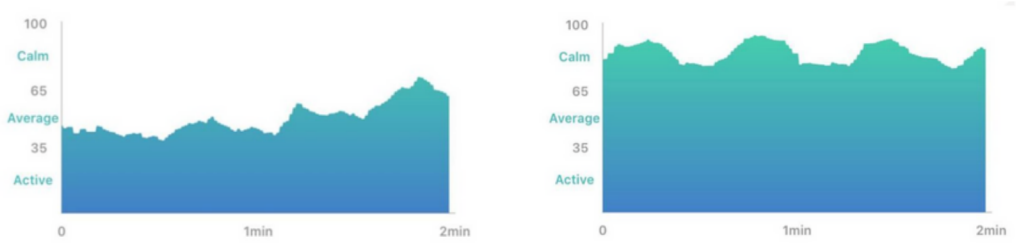
It is important to again note that this is a limited study that should not be assumed to have any merit beyond thoughtful field research with intentions to positively influence practice. It is also important to note that in one of these cases (Participant 3), the score went down. In that case, Participant 3 happened to be a mother who brought her child to the experiment. Approximately fourteen (14) minutes into the experiment, the child (who was being supervised by the participant's mother) began to cry. A follow-up interview with the participant indicates that the interruption to the participant's ability to focus and maintain calm during the experiment can be attributed to the crying baby. Further studies would limit this sort of

situation, where possible. However, from a practical standpoint, it is important to note that while exercise seems to have positive impacts on one's personal state, it cannot overcome certain environmental factors (like a mother hearing her child's cry).

Still, given the limitations of the experiment, the EEG results are promising enough for us to recommend exercise as an intervention to improve the student or employee experience, especially considering its additional health benefits.

Putting it into Practice

In this study, we were able to demonstrate how a short bout of exercise can reduce cognitive workload while maintaining peak cognitive performance. Subjects performed the executive functioning challenge at the same levels before and after exercise but with significantly lower mental strain after they completed the exercise sequence. Expending less energy while completing cognitively strenuous tasks can conserve a great deal of mental bandwidth. By including exercise as a standard practice, wellness may be enhanced by preventing feelings of burnout. With all of these benefits, would one sit around all day? That rhetorical question belongs in our schools, our systems, and ourselves.



One participant's real-time EEG scores* before *and* after *exercise.

Guided by the anchor method described above (8:00 cardio, 2:00 strength, 8:00 cardio, 2:00 balance), there seems to be great opportunity to create exercise routines that would fit into a standard work- or school day. Schools have an organic fit for this work in their health/physical education curricula. Physical Education departments would be wise to enhance existing offerings with a growing understanding of how exercise can holistically benefit the student experience. The same is true for businesses and professional organizations. These organizations create learning opportunities for social emotional learning and healthy communication, why not take 20 minutes to

enhance focus and calm?

Prolonged sedentariness has been connected to mental health issues like major depressive disorder (Schuch et al., 2017) and a variety of physical health concerns, including heart disease (Michos, 2022). Meanwhile, a wealth of research connects exercise to improvements in mental and physical health - this whitepaper adds to that understanding with a direct connection to improvements in focus and calm after a 20 minute exercise routine.

Whether we are avoiding the deleterious effects of prolonged sedentariness, improving mental and physical health outcomes, or aimed at elevating cognitive performance, it is clear that exercise is a necessary and powerful intervention.

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Appendix

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