

Method

Participants

The study was a random cross-over experiment, and sixty volunteers participated in the experiment. The number of participants was that a minimum of 10 individuals per variable are needed for regression problems with 6 variables. The full trial protocol was followed by 58 subjects (27 men and 31 women; 20-30 years; maximum oxygen consumption 35 -55 mL/kg/min). Two participants could not participate in the study due to their time schedules. Data indicating that linear regression models need at least two participants per variable for an accurate estimate of regression coefficients, standard errors, confidence intervals, and adjusted R - squared helped to justify this sample size. Volunteers had to be between 18 and 40, and they couldn't have any physical or mental illnesses that would have affected how well they performed any of the activities. Volunteers who worked night shifts or had a recognized sleep issue were not allowed to participate to account for the negative impact that sleep deprivation had on cognitive function.

Experimental design

Five visits to the lab were needed from the volunteers. Volunteers in Task 1 first became accustomed to the cognitive battery, assessments, and scales before doing an escalating treadmill test to assess cardiovascular health. A scaled Bruce procedure was employed as the incremental treadmill protocol. Every 15 seconds, the test's speed and/or inclination are increased until the individual cannot endure it. The test starts with a leisurely walking pace. Due to the connections between cognition and health that have been discovered, as well as how physical exercise affects the brain, cardiorespiratory fitness was evaluated. To make the participants accustomed to the test they were instructed written and verbally and also rehearsals for each of the tasks for a minimum of 5 minutes.

In 2-5, processes Volunteers conducted either a cognitive, physical, psychological, or control intervention spanning around an hour throughout these periods. A cognitive battery spanning 20 minutes was shortly before and after the cognitive intervention. Volunteers were asked to fill out questionnaires meant to gauge their efficacy and cognitive assessment of the impending process before the baseline test. The intervention's perceived effort and stress were collected at its conclusion but before the post-intervention cognitive test. The scores they had given earlier treatments were not available to the volunteers.

Volunteers were instructed to report to the laboratory drinking plenty of water and sleeping for at least 7 hours before each session. They were also instructed to abstain from drinks, and strenuous activity during the day previously. At the same time of day (within a window of around one hour), each volunteer finished the activities on their own. After the five testing sessions, participants received a \$200 gift card as payment for their commutes expenses.

Experimental and control Interventions

Cognitive Intervention

Participants performed a task similar to a Stroop color-word task for a duration of 1 hour

This task has four colors as words and the word color can be different for example the displayed word is yellow but the text displayed on the screen is with green color. Participants have to choose the correct ink color in 1.5s, each participant's accuracy and speed are calculated based on their performance. Quickness and correct answers lead to better accuracy. The accuracy of the intervention was evaluated for participation. The average accuracy (mean standard deviation) was 97%.

Physical Intervention

This task was walking for 1hr on a treadmill at 6km/hr speed with a weighted suit equivalent to 30% of body weight, and heart rate was monitored every 10 min and subsequently, the weight of the suit and treadmill's speed were changed to standardize the workload. Maintaining effort during a physically demanding task demands cognitive control to keep going even after growing pressure and may lead to eventual cognitive control problems. It takes cognitive control to continue through a physically demanding activity despite developing discomfort, which might eventually result in cognitive control issues. Heart rate was constantly monitored during the treadmill exercise, and every 10 minutes, the Borg Rating of Perceived Exertion was used in this process. The weight of the suit and/or the treadmill's rate was modified, as needed, to standardize the effort and keep the Borg Rating of Perceived Exertion between "fairly hard" 13 ratings and "hard" 15 ratings during the duration of the process. The vest's weight is 17-27 kg.

Psychological Intervention

With the use of a protocol for muscle stimulation, it is intended to generate the negative emotional state of panic. This state will start the emotional regulation process, which is known to use cognitive control resources. It has also been demonstrated that fear created by conditioning methods involves executive functioning and demands attention. In this study, an unpleasant stimulus was repeatedly coupled with a neutral stimulus, and as a result, participants learned that the neutral stimulus always came first. Once this is realized, there is less exposure to the unpleasant impulse as simply the presentation of the neutral stimulus alone results in the conditioning of a fear response. To prevent unintended movement, participants were tied across the chest, hips, and right ankle during this procedure. Participants were seated straight, with their knees and hips at a 90-degree angle. A high voltage constant current stimulator was used to stimulate the quadriceps of the right leg with two carbon rubber electrodes. Participants in the first phase had 100 Hz simulations for 200 ms each, followed by 20 s of rest. After each process, participants reported their level of pain using a numerical rating scale that ranged from no discomfort 0 to the worst pain with 10. Starting at 25 mA, the stimulation was steadily raised until the subject assessed the stimulation as having a pain rating of 5. The 5th-rated stimulation level was then multiplied by 1.5 and maintained at $(113 \pm 69 \text{ mA})$ for the duration of the session.

During the second phase, the subject was shown a black cross on a white background for 20 seconds after being exposed to a green screen for 15 seconds. When the screen changed from the unconditioned response to the neutral response again during phase 1, participants got the 200 ms of stimulation that was indicated. There were 15 iterations of this procedure..

Participants were exposed to the identical pattern of stimuli during the final phase, but electrical stimulation happened pseudo-randomly

The conditioning phase of stimulation took place on 2 of the 12 instances that followed;

Control Intervention

This task involved a 1 hr viewing of the documentary Earth, which follows the migratory paths of animal families, it was selected because the documentary was engaging and had emotionally neutral content.

Cognitive Battery

Participants performed a 20 min cognitive battery during sessions 2-5

The cognitive battery consisted of four activities each lasting for five min

This task was basically to test cognitive abilities of alertness, working memory, task switching, and Response Inhibition, and while collecting the data reactions faster than 100ms were removed from the analysis

Vigilance and Sustained Attention

The name given to this task was PVT(Psychomotor Vigilance Task)

The participant must concentrate on the yellow signal counter that will appear inside the red box on the black backdrop of this problem, and they must press the reaction key as soon as it does to halt the response counter and report reaction time.

The time between the previous reaction and the emergence of the subsequent stimulus ranged between 2 and 10 seconds.

Responses slower than 500ms were excluded from the analysis

Response Inhibition

In this task, a black header was displayed in the middle of the picture for 900 milliseconds, followed by a black number (1–9) on a white background for 250 milliseconds. Attendees had to click a reaction key as quickly as the numbers appeared on the screen, but they were instructed to hold off on number 3.

Responding to a stimulus when it wasn't necessary to do so is what was meant by errors of commission. A participant making an error of omission refuses to respond when one is requested. The percentage of mistakes as well as the task's overall accuracy were documented. The average response time was noted as a valid response.

Working Memory

a task similar to n-Back was performed

In this job, a digit from 1 to 9 was displayed on a screen for around 500 milliseconds, followed by 2.5 seconds of a white screen until the next digit was displayed.

If the value being displayed matches the value that showed two numbers earlier, members must click the reaction key.

A random generator generated the numbers on the screen, with 1/3rd of the inputs being targets and 2/3rd being non-targets.

Task Switching

Participants in this activity viewed a signal in the middle of the screen for 500 milliseconds, followed by a particular signal for 1000 milliseconds. Target response was presented after one signal with a yellow triangle.

Participants can respond by pressing a key to the left or right depending on whether the objective is less than or larger than five.

and it had a blue circle, which was followed by a randomly chosen signal from (1–9).

Participants had to press a reaction key to the left if odd, or to the right otherwise, it is even

Despite having an equal amount of cue stimuli in each task, the cues were alternately presented at random

The flip value was calculated by dividing the average response time of responses to signals that were different from the reactions from earlier trials by the average response time of reactions to those signals.

Self Efficacy

It was measured using the efficacy scale, where a higher score corresponded to stronger efficacy. For this metric, Cronbach's reliability coefficient was used.

Cognitive Appraisal

Assessing anticipatory cognitive appraisal was done using the Primary Appraisal Secondary Appraisal scale

Participants were required to respond to the comments by considering the upcoming action.

Perceived Stress

A pain intensity scale was used to quantify how much tension was felt.

Participants were informed to indicate the degree of stress they experienced throughout each intervention

The amount of stress experienced during the intervention had to be marked along a horizontal line of 100 mm, with the expressions "not stressful at all" to "extremely stressful"

Perceived stress calculated using a visual analog scale, correlates with physiological signs of stress

Subjective Workload

Each intervention and cognitive battery's subjective workload were measured using the NASA TLX scale this scale's overall workload has a Cronbach's reliability coefficient of 0.71

Each question was scored by participants using a scale that was the descriptors extremely high and very low served as anchor points and were separated into 20 equal intervals. Five times this score was applied., giving each of the subscales a final score between 0 and 100 that was then averaged.

Statistical analysis

The effects of the therapies on future mental performance were examined using ANOVA in the cognitive act of every mental task. Time and intervention were employed as factors.

The post-intervention cognitive battery was used to compare each intervention's effects using Friedman's ANOVA for repeated measurements. For each intervention independently, background and post-intervention cognitive performance variations were determined using the Wilcoxon matching pairs signed ranking test. An administration of repeated observations for x times ANOVA was utilized to evaluate how the four therapies affected the subjective workload felt throughout the benchmark and post-intervention variety of cognitive. Using repeated measurements, the effect sizes for the normal distributions were evaluated. With the following explanatory thresholds: small 0.02 to 0.12, medium 0.13 to 0.26, and greater than 0.26, Analyses of variance were calculated as partial eta squared. We utilized lots of different regression models for every one of the interventions to examine self-efficacy and cognitive evaluation, as well as Expected cognitive performance, as well as felt stress, and perceived effort. Because of this, performance in this activity was used as the dependent variable. The study performed for our first goal revealed that the PVT responded best to all three interventions. Sex, age, and baseline cognitive test performance were first taken into account in the model. established link between fitness and the benefits of exercise on cognitive function, fitness level was taken into consideration throughout the first stage of the physical intervention.. stress, and workload were additionally added to the models, first individually and then collectively, to assess their individual and collective contributions to the transition in mental performance. The value was set at p less than 0.05 in all studies. All data's mean and SD are shown.

Results

Intervention Effects on Cognitive Performance

The results of the PVT were responsive to treatments in all domains. The experimental interventions decreased future cognitive performance due to an interaction between intervention and time . The control group's average response time was steady ($p = 0.590$, $\eta^2 = 0.005$), but it slowed down after the cognitive, physical, and psychological interventions ($p = 0.001$, $\eta^2 = 0.313$). Performance before to interventions was similar ($p = 0.530$, $\eta^2 = 0.013$).

The cognitive intervention had solely negative effects on the SART's performance. Accuracy reduced after the cognition intervention p equal to 0.038, and it remained same after the physical p equal to 0.092, psychological ($p = 0.0105$), and control ($p = 0.930$) treatments. Additionally, accuracy was comparable between baseline and post-intervention tasks.

There was no interaction between treatments or the main impact on the proportion of commission mistakes that has growth in all three interventions with ($p = 0.009$, $p^2 = 0.113$). . The control ($p = 0.280$), physical ($p = 0.224$), and psychological ($p = 0.381$) interventions had no effect on errors of omission, while errors become more after the cognitive intervention ($p = 0.001$). Both intervention and time did not affect the average reaction time .

Except for the cognitive intervention, all therapies resulted in improved in n back task. At baseline or after the intervention, accuracy did not differ across the various therapies. therapies, accuracy remained stable over time. With the exception of the cognitive intervention, .The cognitive intervention had no effect on reaction time ($p = 0.194$, $\eta^2 = 0.029$), but the physical ($p = 0.026$, $\eta^2 = 0.084$), psychological ($p = 0.006$, $\eta^2 = 0.124$), and control treatments did. At baseline ($p = 0.130$, $\eta^2 = 0.034$) or post-intervention ($p = 0.155$, $\eta^2 = 0.030$), there was no difference in reaction time across therapies.

Intervention and time effects on the subjective workload of the cognitive battery

treatments had an impact on the workload for every one of the cognitive tests. ($p = 0.045$, $\eta^2 = 0.078$). The psychological p equal to 0.795 , $\eta^2 = 0.002$ and control ($p = 0.435$, $\eta^2 = 0.019$) treatments had no effect on subjective workload, while the cognitive ($p = 0.002$, $\eta^2 = 0.249$) and physical p equal to 0.046 , $\eta^2 = 0.115$ interventions did. The baseline cognitive battery's subjective effort for each intervention was comparable ($p = 0.886$, $\eta^2 = 0.006$).

Effects of Cognitive Appraisal and Self-Efficacy on Post-Intervention Cognitive Performance

Age, sex, PVT, and cardiovascular health (only for physical) were all factors taken into consideration by all models (Steps 1-5) that indicated post-intervention PVT performance for all types of therapy (Table 3). Baseline performance was the only factor in the hierarchical model that could accurately predict each intervention ($p < 0.001$). After effects were unaffected by self-efficacy, primary cognitive evaluation, or secondary cognitive appraisal.

Effects of Intervention's Subjective Workload and Perceived Stress on Post-Intervention Cognitive Performance

From 1 to 4 steps that incorporated, sex, PVT, and cardiovascular health (only for physical) also predicted results on the PVT post-intervention. In all models, baseline performance was a highly significant predictor ($p < 0.001$). Only after added to the original Only for the cognitive intervention did felt stress ($p = 0.018$) and subjective workload ($p = 0.035$) contribute considerably to the model (Step 4) of all variables, accounting for an additional 2 percent of the variation

Discussion

it is shown that completing an assignment that is demanding logical command reduces the productivity of future cognitive tasks and there is reduced cognition after the cognitive intervention

In comparison to physical and psychological interventions, the average response time was seven percent longer on the PVT. after the cognitive intervention and was 3 percent and 4 percent slower after physical and psychological interventions respectively

And it was found that performing cognitive intervention had a negative impact on response time on the n-Back test and the SART task Except for cognitive intervention, All the other interventions had shown a faster reaction time post-intervention

The influence of previous task performance tends to be most pronounced when two activities are comparable in their domains

When considering cognitive issues, one should take into consideration both physical and emotional pressures because PVT performance was unsatisfactory across all experimental procedures.

Along with gains in memory, the emotional workload was higher than baseline following cognitive function and physically demanding work, but it remained stable over time

The ability to keep efficiency at a sufficient level is probably lessened if task duration or complexity are raised, while higher effort may be sustained for brief periods

It is important to use subjective metrics in addition to changes in performance when determining a person's vulnerability to performance declines

sleep deprivation and mental fatigue have a link with the higher perceived workload

Greater increases in the effort are assumed to be connected because the replacement effort is believed to protect tasks or activities that are crucial to the individual or have an effect on safety, with higher degrees of productivity preservation.

Performance diminishes when demands are low

Low demands result in less of a requirement for good productive control and frequently poorer quality. This approach may assist in explaining the consistently greater losses in the PVT when compared to the activities of response control, and processing speed. higher levels of involvement required by these activities, such tasks may be less prone to performance degradation with moderate levels of additional effort along with the highly engaged that exist already. In any event, as activities get more time-consuming, difficult, or unexpected, it is important to take that capability into account.

After correcting for age, sex, and ability on the normal cognitive test, efficacy toward and cognitive assessment of the treatments have been unable to indicate later mental performance. Efficacy is a variable that influences performance and behavior and may influence a person's capacity to cope with stress

It is assumed to have a driving element that impacts engagement and the extent to which a person's involvement with particular behaviors for attaining the desired output.

attendees were asked to rate their measure of the efficacy of the therapies rather than their results on the previous cognitive test.

The effectiveness of the treatment was anticipated to impact the cognitive control needed for the task

The study assumption was minimizing the performance impact would come rather than seeing involvement as a danger, However, making the difference between a difficulty and a risk may be essential in figuring out whether similar practices would be beneficial in the future.

It's possible that different outcomes would have been obtained had self-efficacy been measured at a different time point, like just before the session memory test and both before and after the session greater understanding of a variety of situations helps to boost self-efficacy.

tasks that need cognitive control are said to be effortful. However, the effort is a subjective concept that depends on individuals' efficacy, the judgment of their abilities, and capacity.

although it might be because this intervention had the most effects on performance in the future. Further, the minor level of damage in the experimental treatments may explain the difficulty to detect the greater link between felt stress, subjective workload, and post-intervention cognitive function.

The idea of compensatory effort may have partially explained this outcome.