EEG alpha and theta oscillatory responses to a Go/NoGo task performed during submaximal exercise at light, moderate and hard intensities

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Declarations
The authors declare no conflicts of interest and no financial gain associated with this research.

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ABSTRACT

The aim of the experiment was to investigate changes to behavioral and electrophysiological correlates of selective attention and response inhibition due to simultaneous performance of exercise at light, moderate and hard intensities. Twenty-eight healthy active and right-hand dominant adults (16 Females, 24.1 ± 4.7 years), performed a Go/NoGo task and had EEG recordings taken during submaximal aerobic exercise on a stationary cycle ergometer at light, moderate and hard perceived intensity levels. In contrast to previous reports of cognitive decrements during high intensity exercise and increasing frontal alpha power with increased exercise intensity, the effect of exercise intensity was not significant in linear mixed effects modelling of Go/NoGo task accuracy, response times and frontal alpha and theta power. The experiment also explored resting state individual alpha frequency as a marker of cognitive control during exercise but found no significant associations with Go/NoGo performance or frontal activity. Methodological differences related to exercise intensity may explain the divergence between present and previously reported findings. Specifically, there was incongruence in ratings of perceived exertion between the graded exercise test and Go/NoGo performance conditions for light, moderate and hard intensity conditions. Future investigations should employ more complex cognitive tasks and more reliable approaches to determining individual workloads for exercise intensity conditions.

Introduction

Response inhibition and selective attention are key executive functions for maintaining goal-oriented behaviour (Diamond, 2013): response inhibition is important for preventing unwanted behavior (Nigg, 2000), while selective attention enables discrimination of task-relevant and irrelevant information (Johnston & Dark, 1986), though these processes might operate concurrently for goal-oriented behavior (Erika-Florence, Leech & Hampshire, 2014). The Go/NoGo task has classically been used to assess response inhibition (Simmonds, Pekar & Mostofsky, 2008) and more widely, cognitive control (Criaud & Boulinguez, 2015). Recently, Hong et al. (2017) used a modified Go/NoGo task that included a spatial 'attend' or 'ignore' cue prior to the presentation of a 'go' or 'nogo' stimulus, which demonstrated the ability to differentially evaluate both selective attention and response inhibition.

While cognitive task performance is typically assessed in a rested state, several populations such as athletes, armed services personnel and first responders often require the application of these cognitive functions these during periods of intense physical exertion (Blakely, Kemp & Helton, 2016) that may suppress cognitive performance (Lambourne & Tomporowski, 2010; McMorris & Graydon, 2000; Tomporowski, 2003). The requirement to simultaneously maintain exercise demands alters cortical activity patterns compared with cognitive processes at rest (Robertson & Marino, 2015). Impaired cognitive performance due to high intensity exercise has not been attributed to exercise-related changes in cerebral blood flow (Komiyama et al. 2020) and might be more closely related to depletion of self-regulatory mechanisms (Pageaux et al., 2015; Van Cutsem et al. 2017), which have been associated with frontal cortex networks (Miller & Cohen, 2001). Alternatively, heightened frontal cortex activity associated with high intensity exercise (Mandrick et al., 2013) suggests that diminished cognitive function during heightened physical exertion might be due to competing demands on frontal networks (Blakely, Kemp & Helton, 2016).

One approach to investigating cortical activity responses to exercise has involved the use of electroencephalography (EEG; Bailey et al., 2008), which records electrophysiological activity from the scalp that reflects the post-synaptic potentials of underlying pyramidal neurons in the neocortex. Oscillatory EEG characteristics can be grouped according to 5 frequency bands: delta (~1-4 Hz), theta (~4- 7 Hz), alpha (~8-12 Hz), beta (~13-30 Hz) and gamma (~30-80 Hz). Of these, the alpha and theta band power have been traditionally associated with cognitive function (Rodriguez-Larios & Alaerts, 2019). Increased alpha power has been associated with heightened top-down inhibitory control mechanisms which are necessary to maintain cognitive performance (Klimesch, Sauseng & Hanslmayr, 2007;

Pfurtscheller et al., 1996). For example, in spatially lateralised tasks, alpha power increases in the task-irrelevant hemifield but decreases in the task-relevant hemifield, suggesting a role of alpha suppression in the encoding of task-relevant information, and alpha facilitation in ignoring distractors (Sauseng et al., 2009). Theta activity has been argued to reflect the coordination of cortical regions within networks that serve cognitive processes (Sauseng et al., 2010) though, alpha and theta activity might both contribute to top-down inhibition and organization of cortical function (Harmony et al., 2009). Gratton (2018) proposed that alpha and theta oscillatory activity contribute to cognitive control through complimentary processes where alpha activity serves to maintain task-relevant information and theta activity contributes to information updating. Increased theta power has been generally associated with enhanced executive function (Klimesch et al., 1997) and more specifically, with heightened attentional control (Cavanagh & Frank, 2014). In frontal brain regions, both theta and alpha power have been associated with response inhibition (Kirmizi-Alsan et al., 2006).

Relative to research investigating alpha and theta correlates of selective attention and response inhibition, less work has described changes in these EEG bands due to exercise. Bouts of exercise increase alpha (Gutmann et al., 2018) and theta (Griggs et al., 2023) power in subsequent resting state recordings. There is a limited set of investigations of alpha and theta changes during exercise. Robertson and Marino (2015) demonstrated increased frontal alpha activity during exercise with incrementally increased intensity levels. Bailey et al. (2008) demonstrated increased frontal-central alpha and theta power with increased exercise ergometer workload. In both studies, once exercise intensity reached near-maximal levels, alpha and theta power decreased (Bailey et al., 2008; Robertson & Marino, 2015)

While increased frontal alpha (Harmony et al., 2009) and theta (Yamanaka & Yamamoto, 2010) have been reported for Go/NoGo task performance, there is an absence of work investigating the alpha and theta EEG activity of Go/NoGo task performance during exercise. Thus, it is unclear whether alpha and theta EEG components might reflect decreased Go/NoGo task performance under high intensity levels (Smith et al., 2016). Therefore, the aim of this study was to assess the influence of exercise intensity on concurrent Go/No task performance and frontal alpha and theta EEG power.

Methods

Participants

A convenience sample of sixty participants were recruited. Due to technical issues with EEG hardware, EEG recordings were only available for twenty-eight of these participants, resulting in an analysis with twenty-eight participants (16 Females, Mean Age 24.1 ± 4.7 years). Inclusion criteria required participants to be aged 18-45 years, have a body mass index (BMI) of 18.5-29.9 kg.m^2, have normal or corrected-to-normal vision, and have proficient English according to the Common European Framework of Reference for Languages Global Scale (Council of Europe, 2022) to understand inventories and instructions. Participants were required to have a moderate or high physical activity level based on the International Physical Activity Questionnaire (IPAQ) – Short Form (Craig et al., 2003; Lee et al., 2011) and be cleared to engage in vigorous exercise according to the ESSA Adult Pre-Screening Tool (APSS; Norton et al., 2012). Exclusion criteria included current or recent history of regular smoking or vaping, a history of endocrine, metabolic, psychiatric, neurological, cognitive or language disorders, and the use of cardiovascular or psychotropic medications that could influence physiological or EEG responses. Individuals interested in participating completed online screening to ensure they met inclusion criteria and did not have any exclusion conditions. Participants completed the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989) to categorise poor vs good sleep quality. Participants were recruited via recruitment flyers and social media posts and received an AUD$200 research honorarium. Ethics approval of the research protocol (protocol number: 5236) was obtained from Flinders University Human Research Ethics Committee and all participants provided written informed consent prior to commencing their participation. See Table 1 for participant characteristics.

Table 1. Participant characteristics

Gender	Sleep Quality		Age (years)	Body Mass Index (kg/m^2)	Weekly Physical Activity (METs, min/week)
Female 16	Good 16	Mean (SD)	24.1 (4.7)	23.6 (3.0)	2,089.9 (1,326.4)
Male 12	Poor 12	Range	18, 36	18.8, 29.1	612.0, 5,518.0

Participant sleep quality rating was based on the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989) and weekly physical activity was obtained from the International Physical Activity Questionnaire (IPAQ) – Short Form (Craig et al., 2003; Lee et al., 2011). Age, Body Mass Index and Weekly Physical Activity values are presented as mean (standard deviation).

Cued Go/NoGo task

Top-down selective attention and response inhibitory control processes at increasing levels of exercise intensity were assessed with a spatially Cued Go/NoGo task adapted from Hong et al. (2017). The task was conducted through OpenSesame (Mathôt et al., 2012) running on a Windows operating system. Stimulus output was displayed to the performer via head worn augmented reality (AR) glasses (Nreal Light, Nreal, Beijing, China) with 52° diagonal field of vision OLED display and a 60 Hz refresh rate. During stimulus display, the background remained translucent so that the participant can view the environment through the glasses. Left and right index finger responses were based on two customised response button boxes mounted on the cycle ergometer handlebar. Response buttons were mapped to keyboard input, which was read by OpenSesame.

The task stimulus display began with a central white fixation cross (about 1.38° x 1.38°) and two left and right location markers based on white hollow boxes (about 2.39° x 2.39°) located below and lateral to the fixation cross. Participants maintained central fixation throughout the task. At the start of each trial, a white arrowpoint spatial cue replaced the fixation cross for 200 ms. The participant was instructed to direct attention to the spatially cued location marker and ignore the opposite location marker. The spatial cue was then replaced with the fixation cross for a cue-target interval of 1,000 ms. Next, a white target "+" or "x" stimulus is presented within one location marker for 200 ms. If the "+" appeared in the attended location marker (Attend-Go target), the participant pressed the key that spatially corresponds to the attended location marker. If the "x" appeared in the attended location marker (Attend-NoGo target), the participant was not to press a key. For targets appearing in the ignored location marker, the participant did not press a key if a “+” (Ignore-Go target) or “x” (Ignore-NoGo target) was presented. After 200 ms, the target is replaced by the hollow location markers. Responses could be made immediately after target presentation but must have been made within 1500 ms following target presentation. Trials were spaced by a fixed 1500 ms inter-trial interval with the fixation cross and location markers displayed during this interval. See Figure 1 for example stimuli and timing of the Go/NoGo task.

The task involved eight experimental conditions based on two spatial cue conditions (left and right), two attend conditions (attend and ignore), and two go/nogo conditions (“+” and “x”). The eight experimental conditions were presented randomly with a 50% probability of spatial cue presentation and a 50% probability of go and nogo targets. The task as organised into a block of 72 trials with nine cycles of the task conditions presented in a randomized order. The duration of a block was about five minutes.

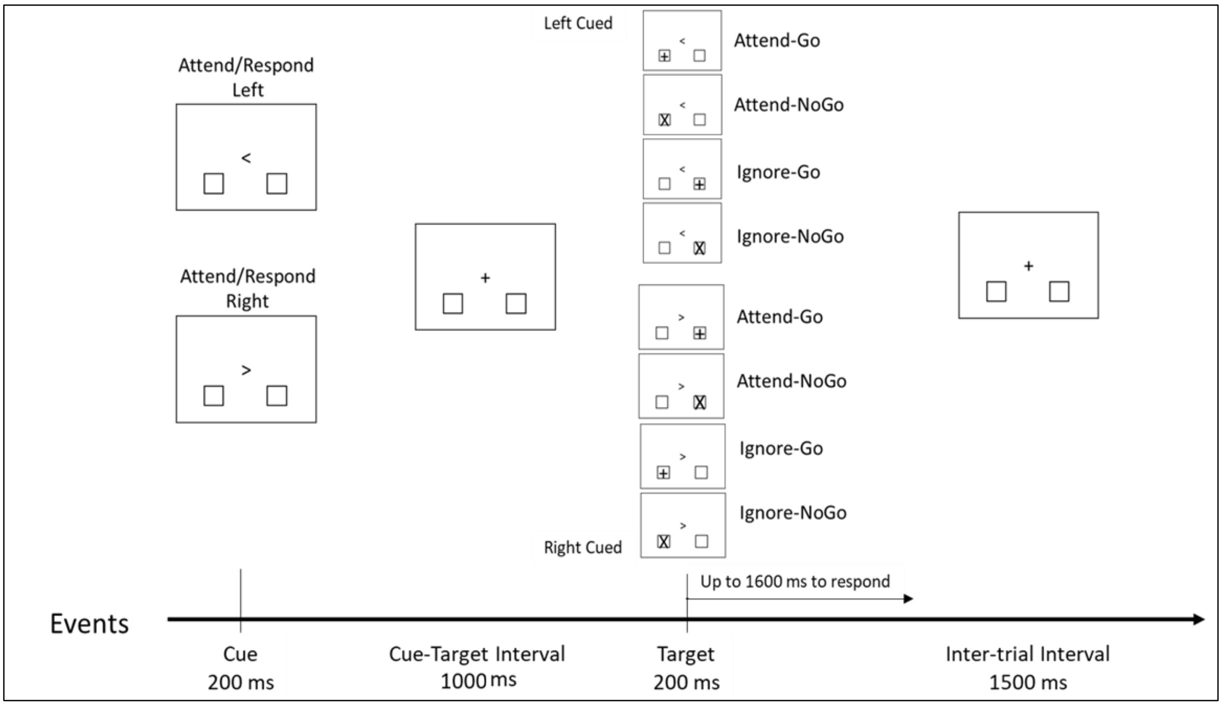

Figure 1. Cued Go/NoGo task trial event timing with cued and target conditions (Hong et al., 2017).

Graded Exercise Test

Graded exercise testing was conducted on an ergoselect 5 (ergoline GmbH, Bitz, Germany) upright electromagnetically braked cycle ergometer following standard testing protocols (Beltz et al., 2016; Fletcher et al., 2013). Participants first completed a 5-minute warm-up at 25 W before power output increased by 25 W every two minutes until volitional exhaustion or participants were unable to maintain a pedal cadence between 50 and 80 rpm while remaining seated. Participants were aware of cadence but not target or current work output or interval duration and no verbal encouragement was provided.

Rating of perceived exertion (RPE) and ergometer power output was measured during the warm-up and each increment of the GXT. RPE was collected based on Borg's RPE 6–20 Scale (Borg, 1982) in the final 45 seconds of each increment stage.

EEG Recording and Pre-processing

EEG recordings were completed at rest and during Cued Go/NoGo task performance from 32 active Ag/AgCl electrodes (recording channels: Fp1, Fp2, F3, F4, F7, F8, Fz, FC1, FC2, FC5, FC6, C3, C4, Cz, T7, T8, CP1, CP2, CP5, CP6, P3, P4, P7, P8, Pz, O1, O2, Oz, TP9, TP10) fixed to an elastic mesh cap (Brain Cap, Brain Products GmbH, Gilching, Germany). EEG signals were amplified with a LiveAmp 32 amplifier (Brain Products GmbH, Gilching, Germany) at a 500 Hz sampling rate. Electrode placement followed the 10/20 system and electrode channels were referenced to Cz, with the ground electrode positioned at Fz. Impedance for each electrode were kept below 5 kΩ during recordings. Electrooculogram (EOG) recordings were obtained from electrodes placed below the left eye and the outer canthus of the right eye, respectively. Channel impedance detection and continuous recording were undertaken in BrainVision Recorder (Brain Products GmbH, Gilching, Germany). For ERP analysis of the cued Go/NoGo task, wired event trigger output from OpenSesame to a LiveAmp Trigger and Sensor Extension Box (Brain Products GmbH, Gilching, Germany) occurred at cue, target and response events. Event markers distinguished left and right spatial cues, attend and ignore conditions, go or no go targets, and correct or incorrect responses.

Task EEG data were pre-processed using EEGLAB (Delorme & Makeig, 2004) and custom scripts using MATLAB (R2022a, The Mathworks, USA). Noisy and unused channels were removed based on visual inspection. The data were then band-pass (1–100 Hz) and band-stop (48–52 Hz) filtered using zero-phase fourth-order Butterworth filters, and epoched −1 s to 4s relative to the beginning of the cue. Independent component analysis (ICA) was conducted using the InfoMax algorithm, and ICLabel was used to remove artifacts. Data were then checked for remaining artifact via visual inspection and trials were removed if necessary (e.g., remaining blinks, non-stereotypic artifacts). Missing channels were then interpolated, and data were re-referenced to the common average.

Procedure

Participants were instructed to remain hydrated and refrain from consumption of caffeine or food , as well as refrain from alcohol consumption and use of stimulant, depressant or psychoactive recreational substances for at least three hours prior to the sessions. Participants individually attended a university laboratory for two sessions. In the initial session, a participant was familiarised with the Borg 6-20 RPE scale and the Go/NoGo task, including task practice trials. They then completed the graded exercise test.

Participants returned 2-5 days after the first session for testing of Cued Go/NoGo task performance during light, moderate and hard exercise intensities. Following EEG cap fitting, resting-state EEG was recorded using a 2-minute eyes-open and 2-minutes eyes-closed protocol in a seated position. The purpose of the resting EEG measure was to quantify individual eyes-closed resting state individual alpha frequency (IAF).

After resting state EEG recording, participants mounted the cycle ergometer and completed a 5-minute warm-up at 25 W followed by three 7-minute workloads that corresponded to their RPE of 7-8 (light), 12-13 (moderate) and 15-16 (hard) in the graded exercise test. Basing exercise intensity on RPE is thought to be more reliable than heart rate since the former is more closely associated with an individual's maximal fitness capacity (Goss et al., 2011; Haile et al., 2015). In each intensity level, the participant first pedalled at the predetermined work output for two minutes to establish stable state before simultaneously performing a block of the Cued Go/NoGo task for the next five minutes. Each workload required a cadence of 50-80 rpm and was followed by a 5-minute recovery period of slow (<50 rpm), unloaded pedalling. Intensity order was randomized between participants and RPE was recorded in the final 20 seconds of each workload.

Data Analysis

Individual RPE and work output from the second session were separately analyzed as outcome variables using mixed effects linear modelling with the lme4 package (Bates et al., 2015) in R (version 4.1.0) with intensity as the fixed factor and participant as the random factor.

For each participant and exercise intensity level, accuracy percentage (responding in Attend-Go trials and not responding in Attend-NoGo and Ignore trials) was calculated over the block of 72 trials. Then for each participant and intensity level, mean response time was calculated for correct Attend-Go trials.

Task EEG data was analyzed in the FieldTrip MATLAB toolbox (Oostenveld et al., 2011). Time frequency representations of alpha and theta power with a 0.5 Hz frequency resolution were obtained using a multi-taper time-frequency transformation based on multiplication in the frequency domain, a time window three cycles long and a Hanning taper. Power was calculated for individual trials before averaging for each exercise intensity. Data were baseline corrected (dB method) to -0.5 to 0 s before the onset of the cue. Frontal theta and alpha power were calculated as the average of fronto-central channels FC1, FC2, Fz, Cz (Hong et al. 2017) during the 1000 ms interval between cue and target stimulus presentation.

Separately, Go/NoGo task accuracy and response time and task-related frontal alpha and theta power were submitted to mixed effects modelling as outcome variables. In these models, exercise intensity was the fixed effect and participant number and intensity order as the random effects.

For each participant, we acquired individual alpha frequency (IAF) estimates from pre-processed (0.1 to 40 Hz filtered), two-minute, resting-state, eyes closed EEG recordings from six occipital-parietal electrodes (P3, P4, O1, O2, P7, P8) using the Philistine package (Alday, 2019) in MNE-Python. This IAF estimation routine uses a Savitzky-Golay filter (frame length = 11 frequency bins, polynomial degree = 5) to smooth the power spectral density (PSD). It then searches the first derivative of the smoothed PSD for evidence of peak activity within a frequency interval of 7 – 13 Hz. For further details, see Corcoran et al. (2018).

As IAF is thought to decrease with age (Klimesch, Schimke & Pfurtscheller, 1993) we conducted Pearson's correlation of participant age and IAF since the distribution did not violate normality assumption ($p = .083$). Spearman's correlation between IAF, frontal alpha and theta, and task accuracy and response time was conducted since distributions for the latter four measures did not meet normality criteria (all $p < .01$). In all tests, a p-value of less than .05 was considered statistically significant. For mixed effects modelling, fixed effects were analyzed with type III Wald F tests and post-hoc pairwise t tests, with Bonferroni correction for multiple comparisons, were performed in case of significant main effects or interactions.

Results

For session two RPE (Figure 2A), there was a significant main effect of exercise intensity ($F_{1,54}$ = 243.67, p < .001), where RPE at each intensity level was significantly different (p < .001) from the other two levels. The main effect of intensity was also significant for work output ($F_{1,54}$ = 154.25, p < .001), where each intensity level had significantly different work output (Figure 2B) than the other 2 levels (p < .001). See Table 2 for mean, standard deviation, and range descriptive values for RPE and work output.

No significant main effect of exercise intensity was observed for accuracy percentage ($F_{2,108}$ = 1.86, p = 0.16; Figure 3A), or response time ($F_{2,108}$ = 2.64, p = 0.08; Figure 3B). There was no significant effect of exercise intensity on Go/NoGo cue-target period frontal alpha ($F_{2,54}$ = 0.13, p = 0.88; Figure 4) or frontal theta ($F_{2,54}$ = 1.53, p = 0.22; Figure 5).

IAF was not significantly correlated with age, r(26) = -.13, p = .52, task accuracy, r(26) = .045, p = 69, response time, r(26) = -.074, p = .51, frontal alpha, r(26) = -.11, p = .32, or frontal theta, r(26) = -0.11, p = .34.

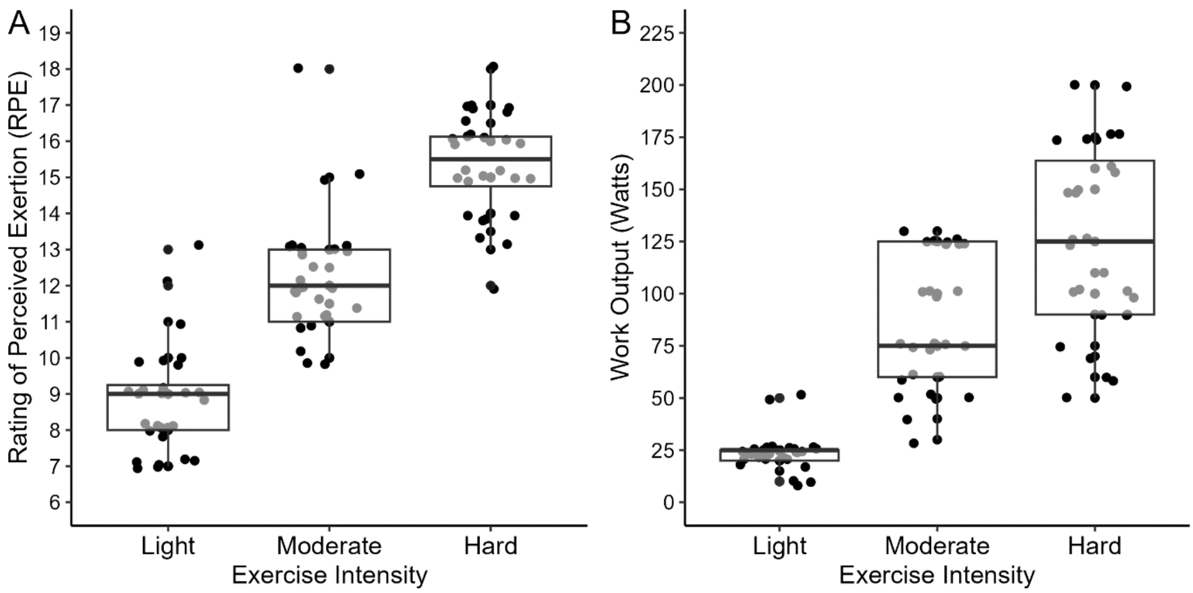

Figure 2. (A) Rating of perceived exertion (RPE) and (B) ergometer work output for Light, Moderate and Hard exercise intensity levels employed concurrently with Go/NoGo task performance. Light, Moderate and Hard intensity levels were based on ergometer work output associated with RPE of 7-8, 12-13 and 15-16, respectively, in a baseline graded exercise test.

Table 2. Rating of perceived exertion (RPE) and work output for exercise intensity conditions concurrent with Go/NoGo task performance

	RPE (Borg 6-20)		Work Output (Watts)	
Exercise Intensity	Mean (SD)	Range	Mean (SD)	Range
Light	8.79 (1.5)	7, 13	23.8 (8.9)	10, 50
Moderate	12.3 (1.7)	10, 18	84.5 (31.7)	30, 130
Hard	15.4 (1.4)	12, 18	125.5 (44.7)	50, 200

Work output for each exercise intensity level was determined in a baseline graded exercise test based on participant reported RPE of 7-8, 12-13, 15-16 for Light, Moderate and Hard intensities, respectively.

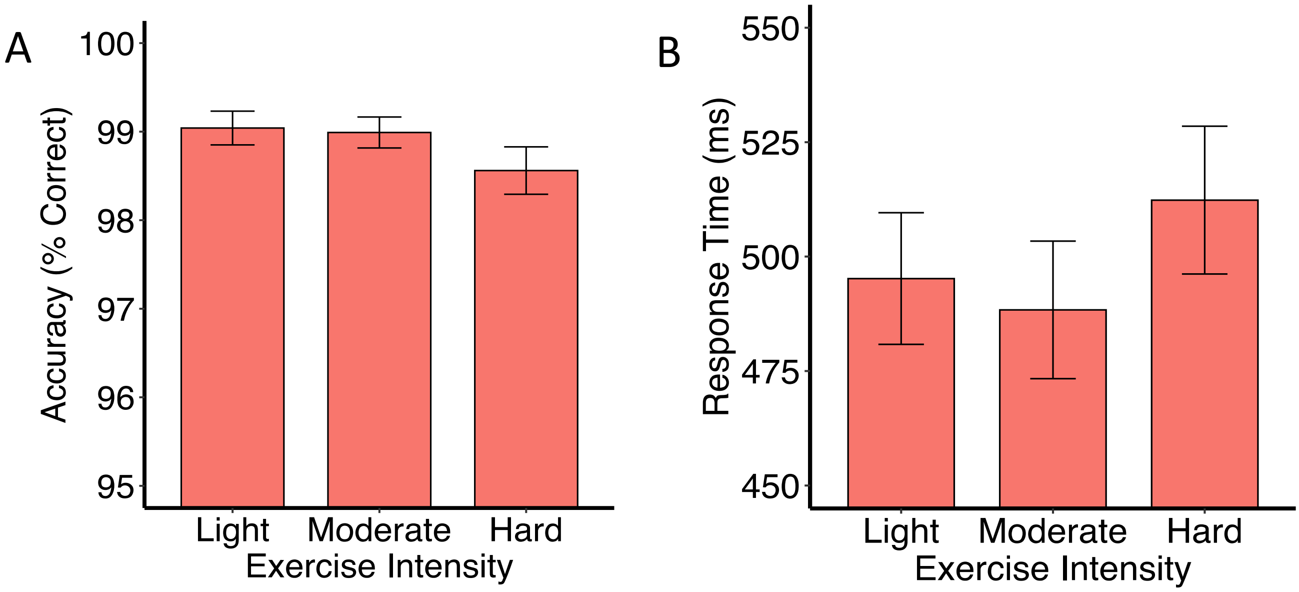

Figure 3. Go/NoGo task (A) Accuracy (% correct) and (B) "Attend-Go" Response Time as a function of exercise intensity.

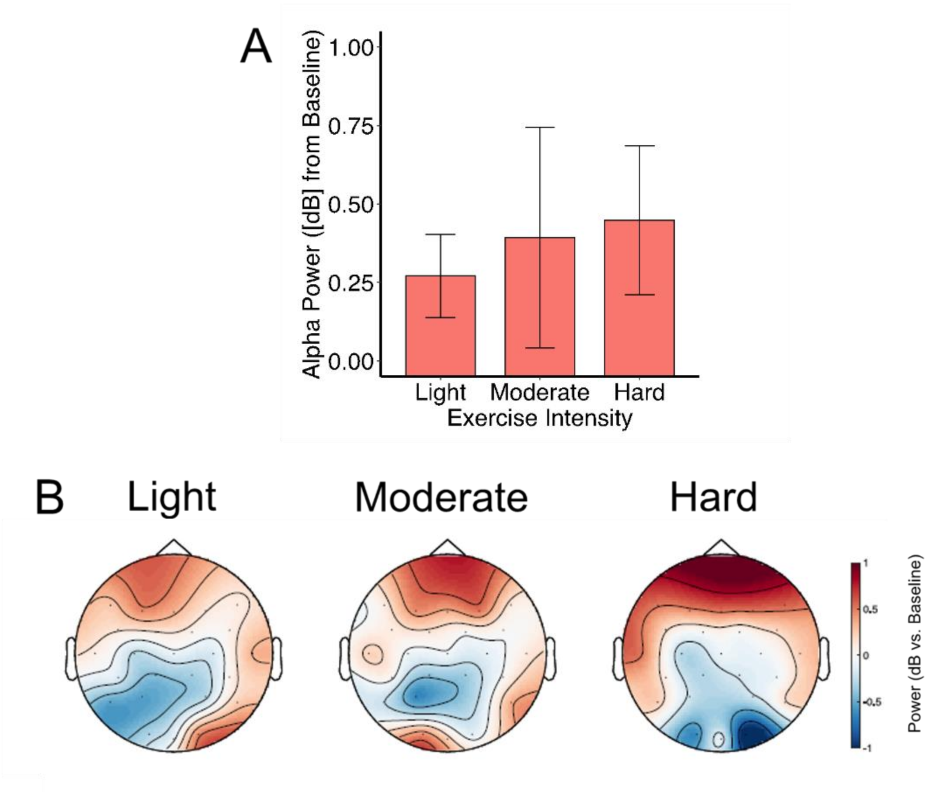

Figure 4. (A) Baseline corrected time frequency topoplots (frequency: 8-12Hz) representing the average scalp distribution of alpha power during the cue-target interval for each exercise intensity. (B) Mean frontal alpha power across exercise intensity conditions.

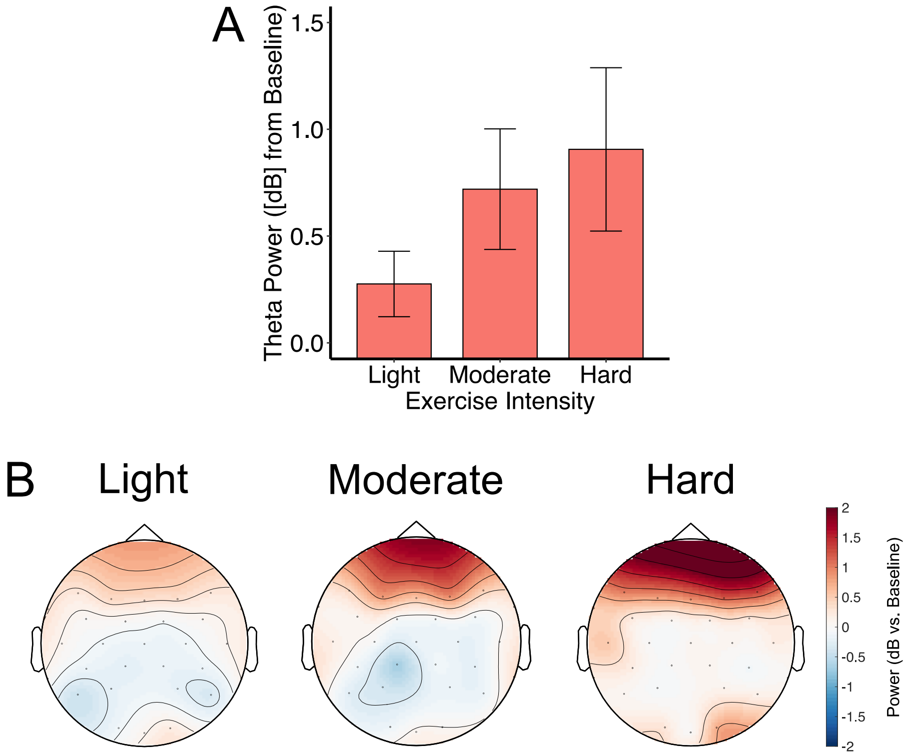

Figure 5. (A) Mean frontal theta power across exercise conditions. (B) Baseline corrected time frequency topoplots (frequency: 4-7 Hz) representing the scalp distribution of average cue-target interval theta power.

Discussion

The aim of the present experiment was to investigate the concurrent effects of exercise intensity on performance and electrophysiological correlates of selective attention and response inhibition. The absence of significant effects of exercise on Go/NoGo task performance and frontal alpha and theta power suggest that selective attention and response inhibition are not suppressed by concurrent exercise at moderate and hard intensities relative to light intensity. The present nulls findings contrast with Smith et al.'s (2016) report of increased Go/NoGo task error rate and response time under high exercise intensity when compared to moderate intensity and rest conditions. More widely, the present results do not align with previous reports of cognitive impairment during exercise (Lambourne & Tomporowski, 2010; McMorris & Graydon, 2000; Tomporowski, 2003). This lack of alignment is indicative of mixed findings in the exercise and cognition literature (Cantelon & Giles, 2021; Sudo et al., 2022). The present results also contrast with previous reports of increasing frontal cortical activity with increased exercise intensity (Bailey et al., 2008; Mandrick et al., 2013; Robertson and Marino, 2015). Taken together, the present behavioral and EEG data do not lend support for the notion that elevated exercise intensity establishes competing demands on frontal cortical resources needed to maintain cognitive control (Blakely, Kemp & Helton, 2016).

The contrast between the present findings and previous reports of suppressed cognition during exercise (Lambourne & Tomporowski, 2010; McMorris & Graydon, 2000; Tomporowski, 2003) might be attributed to methodological differences, an issue which has traditionally limited comparisons between studies (Chang et al., 2012). For example, and specifically to the Go/NoGo task, Smith et al. (2016) utilised a treadmill ergometer whereas in the present experiment, exercise was conducted on a stationary cycle ergometer. In the Lambourne & Tomporowski (2010) meta-analysis and Sudo et al. (2022) review, exercise on a treadmill was found to be more detrimental to cognitive performance that exercise modes involving a cycle ergometer.

In addition to mode of exercise, differences in implementation of exercise intensity might also contribute to lack of consistent findings (Lambourne & Tomporowski, 2010). Specifically, it might be the case that only at very intense, near maximal, exercise intensity, that deteriorate cognitive performance is observed. For example, Mekari et al. (2015), demonstrated slowing on the Stroop task at exercise intensity of 85% of peak power output. More specific to the Go/NoGo task paradigm, Smith et al. (2016) demonstrated loss of task performance at intensities associated with RPE of 18-19 on the Borg 6-20 scale. They did not demonstrate suppressed Go/NoGo task performance at intensities associated with RPE of 15-17, which notably corresponded to the Hard level of intensity employed in the present experiment.

With respect to frontal electrophysiology, Robertson and Marino (2015) demonstrated increased frontal alpha power as cycle ergometer exercise intensity increased (see also, Bailey et al., 2008 for a similar pattern with theta power). Visual inspection of the present data reveals a similar pattern for both frontal alpha and theta power, although the effect of exercise intensity on these measures was not significant. Robertson and Marino (2015) and Bailey et al. (2008) reported marked reduction in frontal alpha and theta power, respectively, when exercise intensity approached volitional fatigue. Frontal alpha power reduction might reflect reduced capacity to maintain cognitive control processes necessary for continuation of exercise (Clements et al., 2021; Gratton, 2018).

In summary, loss of cognitive control during exercise might only be evident at near maximal intensities (Smith et al., 2016; Tomporowski, 2003). As such, the absence of exercise intensity effects on Go/NoGo performance and frontal alpha and theta power in the present experiment might be due to the use of submaximal exercise intensities. Furthermore, although the present analyses indicated significantly different mean RPE between exercise intensity levels, and these means corresponded to target RPE for each intensity level, the range of RPE values from session two indicate some discrepancy with the graded exercise test. This overlap could be partly attributable to the short-term increases in RPE during moderate-hard intensity exercise (Parfit & Eston, 1995), as RPE was assessed at the end a 7-minute workload at session two compared with the end of a 2-minute workload at session one. Further, as the order of exercise intensity was randomised, the preceding exercise intensity may have affected subsequent perceived exertion (e.g., fatigue induced by hard intensity exercise may have increased RPE during subsequent exercise at moderate and/or light intensities (Eston et al., 2007)). Additionally, work rates employed during Go/NoGo task performance could have been moderated by participant motivation towards exerting themselves through exercise (Abbiss et al., 2015). We based exercise workload on RPE as it is thought to more reliably index exercise intensity relative to maximal capacity than use of heart rate (Goss et al., 2011; Haile et al., 2015). However, this might only be the case in appropriately motivated individuals.

Our inspection of resting state individual alpha frequency, as a trait-like marker of information processing speed (Klimesch et al., 1996) and cognitive control (Angelakis, Lubar, & Stathopoulou, 2004), did not reveal any significant correlations with Go/NoGo task performance or task-related frontal alpha and theta power under low to hard exercise intensities. It is possible that the Go/NoGo task was not sufficiently sensitive to individual differences associated with resting state individual alpha frequency. Resting state individual alpha frequency might better differentiate performance on more complex tasks (Klimesch, Schimke & Pfurtscheller, 1993) than the Go/NoGo task. We observed very high accuracy rates with the Go/NoGo task, illustrating low selective attention and inhibitory control processing demands on performance. To our knowledge, resting state individual alpha frequency has not been previously used to inspect individual differences related to electrophysiological correlates of exercise regulation. While we did not observe any significant correlation between resting state individual alpha frequency and frontal alpha and theta power at light to hard exercise intensities, this might be attributed to the aforementioned methodological issues in determining work rates for these intensities.

Conclusion

The present experiment did not demonstrate effects of exercise, at light, moderate and hard intensities, on frontal alpha and theta power or Go/NoGo task performance. Furthermore, resting state individual alpha frequency was not associated with individual differences in frontal alpha and theta power or Go/NoGo task performance during exercise. High accuracy rate and relatively short response times suggest that the Go/NoGo task presented limited challenge to selective attention and response inhibition processes associated with this task paradigm. Moreover, basing work rates on RPE might have introduced unreliable levels of exercise intensity, which limited inspection of exercise intensity effects on behavioral and electrophysiological correlates of selective attention and response inhibition during exercise. Future studies should revisit the effects of concurrent exercise on selective attention and response inhibition with more complex task paradigms and more reliable approaches to establishing individual exercise intensity. Furthermore, future studies need to employ designs which allow exercise influences on frontal alpha and theta activity to be differentiated from task performance effects.

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