The Influence of Induced Anxiety on the P3 Event Related Brain Potentials of Athletes and Novices in a Go/NoGo Task

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An elite athlete employs complex skills during competition that have been learned and perfected over long periods of training. Skills that include kicking, throwing, and hitting are complicated and require heightened motor control, focus, and attention. Attention allocation and motor control may be evaluated by the P3 wave, a neurophysiological measure of cognitive control. The Go/NoGo task is often used to elicit a P3 wave by averaging electroencephalogram readings from frequent stimuli that require a response (Go) and infrequent stimuli that require response inhibition (NoGo). Anxiety may also affect performance, both on the athletic field and in the research laboratory. Physiologically, heightened anxiety is associated with skin conductance responses, triggered by activation of the sympathetic nervous system. The goal of this study was to compare behavioral and neurophysiological responses of athletes and novices during the Go/NoGo task under both calming and anxiety provoking conditions. The hypothesis that participants would perform better following anxiety induction was based on drive theory that suggests motivation to compete creates heightened arousal and allows people to perform at a higher skill level. Since athletes have experience performing under pressure, the anxiety induction manipulation was expected to be more beneficial for athletes compared to novices. Each of the 26 undergraduate participants completed the Go/NoGo task once following a calming manipulation and once after anxiety induction, with the order counterbalanced. Analyses of skin conductance responses and participant reports confirmed that anxiety was induced successfully during the anxiety induction manipulation, and was reduced during the calming manipulation. In contrast to the hypothesis, novices made significantly more errors on the Go/NoGo task following anxiety induction and had reduced P3 amplitudes. In contrast, neither accuracy of athletes nor amplitudes of P3 differed between the anxiety inducing and calming manipulations.

Introduction

An elite athlete employs sophisticated skills during competition, including motor functions that have been learned and perfected over long periods of advanced training. Skills that include kicking, throwing, shooting, and hitting are highly complex and require heightened motor control, focus, and attention. Tan and colleagues (2017) found that elite athletes exhibited higher functional connectivity in cortical areas of the brain related to motor and cognitive functions than novices, or non-athletes. Results of their MRI analyses suggested that athletic training and experience may have produced structural changes in the brains of athletes that increased cortical plasticity and afforded them more control over motor and cognitive functions compared to novices [1].

Attention allocation and motor control can be evaluated using the latency and amplitude of the P3 component. The P3 is a type of event-related potential (ERP). ERPs are voltage changes within the brain in response to stimuli, such as sensory and motor processes, that can be separated into components [2]. The P3 is a component that spikes approximately 300 ms following presentation of a distinctive stimulus. Latency refers to the time from stimulus onset to the point of maximum amplitude, and amplitude refers to the difference between the mean baseline voltage before stimulus onset and the largest peak of the ERP waveform within a specific timeframe following the stimulus [3]. In essence, amplitude measures how strong attention allocation is, while latency is a measure of how fast attention is allocated. An advantage of research with ERPs is that the resolution is in the millisecond range allowing for precise evaluation of brain activity [2]. In addition, the use of ERPs provides a good measure of information processing that does not manifest through a behavioral response. The P3 wave has also been found to be a stable long-term neurophysiological index of cognitive control [4].

The Go/NoGo task is often used to study cognitive control by averaging ERP readings in time locked periods for Go (respond) and NoGo (do not respond) stimuli. The latency and amplitude of the P3 in response to the NoGo condition and the P3 Go conditions are different [3]. NoGo trials are expected to produce greater P3 amplitude and faster latency in comparison to Go trials. The stronger response to NoGo trials is thought to represent both a memory updating process to the infrequent stimuli and a cognitive control process to inhibit a frequent motor response.

The electric currents that make up the ERPs differ across locations on the scalp [3]. NoGo stimuli elicit a P3 wave that differs from Go stimuli in topography in addition to latency and amplitude [3]; topographical differences may underscore distinct functional meanings. Amplitude becomes larger and latency becomes shorter from frontal to parietal electrode sites for typical P3 components. Because of these differences, topography must be included in ERP analyses along with amplitude and latency to provide the definitional characteristics of the P3 wave [4].

Fz, Pz, and Cz refer to the three electrode sites typically used for P3 component analysis [3,4]. Fz is located on the front of the head right above the forehead, Cz is located in the middle on top of the head, and Pz is located on the posterior of the head. All three sites are located on the midline of the brain. Fz is positioned over the prefrontal cortex that is involved with decision making and other executive functions controlled by the frontal-parietal network. The frontal-parietal network is a system of cognitive control in which a decision is made in the prefrontal cortex and then information regarding that decision is communicated to the parietal lobe to execute or withhold an action or response.

ERP readings of the P3 component may be compared to the active decision-making employed by athletes during competition. The Go/NoGo task is reflective of a game-time decision to employ or withhold a motor function. Because of the higher functional connectivity that may be developed in athletes, P3 latency during a Go/NoGo task was expected to be quicker for athletes compared to novices. Similarly, the P3 amplitude of athletes was expected to be stronger, or larger. Expected differences in latency and amplitude were supported by drive theory that suggests heightened anxiety is associated with heightened performance [5]. Drive theory coincides with several other studies postulating that moderate stress activates and enhances the frontal-parietal network [6,7].

Previous studies have found that elite performers and athletes develop cognitive skills that allow them to interpret performance anxiety as more facilitative, suggesting that experience in high-stress environments including athletic competitions allow athletes to better perform under anxiety provoking conditions [8,9]. Experience in anxious situations induces the cortical plasticity leading to greater functional connectivity in athletes. In contrast to the facilitative effects of anxiety that may improve performance of elite athletes, anxiety and emotional states have been found to negatively impact performance of college-aged participants. For example, Qi et al. (2018) used a math task as a stress inducer and noted that P3 amplitude and task accuracy dropped significantly as anxiety increased, showing the possible negative effects of anxiety during performance [9].

Performance anxiety, is a feeling of tension or anticipation of some threatening occurrence in a competitive situation [5]. Somatic signs and

symptoms of performance anxiety include increased blood pressure, increased heart rate, sweating, quickening of breath, clammy hands and feet, nausea, muscular tension, and distorted vision [5]. Electrodermal activity (EDA) measures skin conductance, and can be used to determine the somatic symptoms of arousal. EDA is a reliable way to physically confirm that the autonomic nervous system has been activated.

The goal of the current study was to compare behavioral and neurophysiological responses of athletes and novices during the Go/NoGo task under both calming and anxiety provoking conditions. EDA was used in addition to self-reports of anxiety to confirm that level of anxiety differed between the two conditions. Behavioral differences were evaluated based on number of errors made following the manipulation, and P3 latency and amplitude were used as measures of neurophysiological responses. The hypothesis that participants would perform better following anxiety induction was based on drive theory. Since athletes have experience performing under pressure, the anxiety induction manipulation was expected to be more beneficial for athletes compared to novices.

Methods

Participants

The full sample included 26 undergraduate participants, 14 men and 12 women. Ages ranged from 18 to 23. The majority of the sample was White (57.7%), with 23.1% Black and 19.2% of another race. All participants were right-handed, not on psychiatric medication, and had not consumed alcohol within 12 hours of participation. P3 data was only available for 14 of the participants due to equipment malfunction or experimenter error. Of these 14, six were current athletes (four men), six were novices (two men), and two were high school athletes who no longer played organized sports. These two participants were not included in analyses comparing athletes and novices. Athletes were defined as participants who were currently playing an organized sport for the University of South Carolina Aiken. Four of the six athletes played for the USC Aiken men's and women's soccer teams.

Most participants were recruited through the SONA online system for Introductory Psychology students managed by the Psychology Department at the University of South Carolina Aiken. These participants received research participation credit, a requirement of their course. Other participants were recruited externally, mainly from athletic programs within USC Aiken. These participants each received $5 gift cards to Starbucks for participating.

Design

This study employed a 2 (group: athlete, novice) by 2 (condition: anxiety induction, calming) mixed design. Group was a between subjects independent variable, and condition was a within subjects independent variable. Each participant completed the Go/NoGo task once following a calming manipulation and also after anxiety induction. One-half of the participants received the calming manipulation first and the other one-half received the anxiety induction first. The calming manipulation was a 5 min period during which participants were asked to color a mandala. The anxiety induction was a mental arithmetic task in which participants were asked to consecutively add 13 to the number 1,022, restarting at 1,022 if they made an error. The anxiety induction lasted approximately 5 minutes. The four dependent variables were amplitude and latency of the P3 waves during each Go/NoGo task, and accuracy of responses and response inhibition during each Go/NoGo task. EDA and self-reports were used as manipulation checks to confirm that anxiety had been induced.

Procedure and Measures

Upon arrival for the study, participants were screened for eligibility and informed consent was obtained. After signing informed consent documents, two pre-gelled electrodes were placed on the palm of each participant's left hand. These electrodes were connected to a Biopac MP36, a physiological amplifier used to collect EDA during both calming and anxiety inducing manipulations and while engaged in the two Go/NoGo tasks.

Music was played to make participants comfortable as the EEG cap was fitted based on individual measurements and electrodes applied. Once impendences had reached 10 kohm or below participants engaged in either the calming or anxiety inducing manipulation, based on random assignment. Each manipulation was followed by the Go/NoGo task that lasted an average of 20 min. Participants completed anxiety self-reports four times – before and after the calming and anxiety inducting manipulations. Upon completion of the second Go/NoGo task, demographic information was collected including age, sex, race, socioeconomic status, year in school, major, and athletic history. Participants also completed a measure of trait anxiety.

The study was conducted in the EEG neuroimaging laboratory in the Penland building at the University of South Carolina Aiken. Participants were asked to turn off their electronic devices and were seated in a chair facing the computer. The room was maintained at a comfortable temperature and was kept electronically silent to eliminate EEG interference.

Go/NoGo Task

A Go/NoGo task was used to measure cognitive control and response inhibition. Each task included a total of 400 trials, grouped into eight blocks of 50 trials, lasting about 90 seconds per block. Stimuli consisted of three letters: A, E, and O. Participants were instructed to respond to frequent stimuli (Go) by pressing the down arrow on the keyboard when the letter "E" appeared, and to withhold a response to infrequent stimuli (NoGo) when the letter "O" appeared. They were also instructed to respond (Go) to the letter "A" unless it was immediately following another "A." Trials were split with 80% Go and 20% NoGo, totaling 320 Go trials and 80 NoGo trials. The task was completed twice: once following anxiety induction and once after the calming manipulation for a total of 800 trials per participant. The number of errors were summed separately for Go and NoGo trials for each condition.

Electrophysiological Data

Electroencephalogram (EEG) data was collected using electrodes attached to a 32-channel ActiChamp electrode cap based on the 10-20 system. Vertical and horizontal electrooculograms (EOG) were recorded by four additional electrodes that were placed around the eyes, in order to detect blinks and other eye movements. The left and right mastoids were used as reference points. Data was collected at 500 Hz/channel.

Following acquisition, EEG data was segmented into the 400 discrete trials. Once the data was segmented, a 200 ms period prior to stimulus presentation was used as a baseline correction. Then segments were filtered using a low pass infinite impulse response (IIR) filter of 30 Hz and a high pass IIR filter of .01 Hz. Any trial responded to incorrectly was removed from further analysis. Correct trials were then examined for artifacts. Initially, a semi-automatic process was used involving ideal amplitude, gradient, and frequency. Trials containing EEG and EOG artifacts, like eye blinks or muscle movements were removed. Each remaining trial was then checked manually for artifacts. Artifact free segments were then averaged separately for Go trials and for NoGo trials. Figure 1 shows segmented EEG data for athletes on Go trials compared to NoGo trials. The averaged wave for Go trials was subtracted from the averaged wave for NoGo trials to create a P3 difference wave that represented brain response to response inhibition and quick decision-making. BrainAnalyzer Pro software was used to find the peak amplitude and associated latency of the averaged wave form within 250 and 600 milliseconds after the stimuli was presented. Fz, Pz and Cz were the three electrode sites used for the P3 component analysis.

Anxiety Inventories

The State-Trait Anxiety Inventory (STAI) [10] and an additional 4-item questionnaire constructed by the author were used to provide subjective impressions on how much anxiety each participant felt. The state portion of the STAI included 20 items that reflected an individual's anxiety at that particular moment on a scale of 1 = *not at all* to 4 = *very much so*, with one-half of the questions indicating current levels of anxiety (e.g., I am tense) and the other one-half reverse scored to show lack of current anxiety (e.g., I feel calm). The trait portion of the STAI indicated an
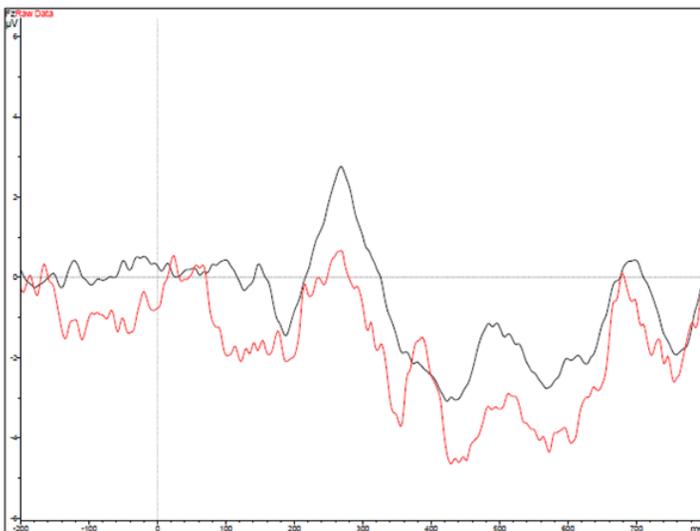
Figure 1. ERP data for athletes that shows the P3 during Go trials (black line) and NoGo trials (red line).
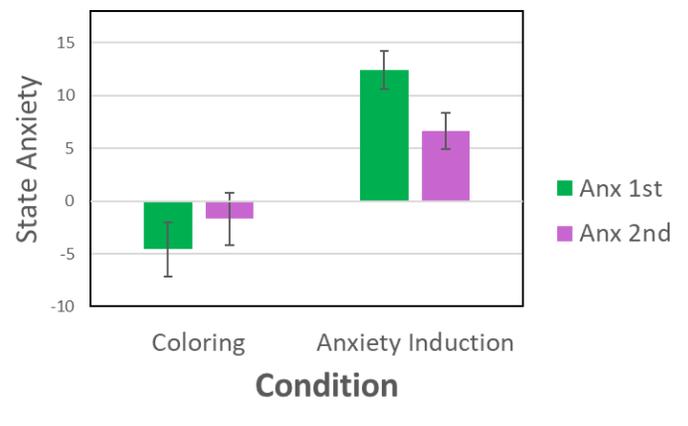

Figure 2. When anxiety was induced prior to the first Go/NoGo task (green bars), the manipulation had a greater effect than when anxiety was induced prior to the second Go/NoGo task (purple bars).
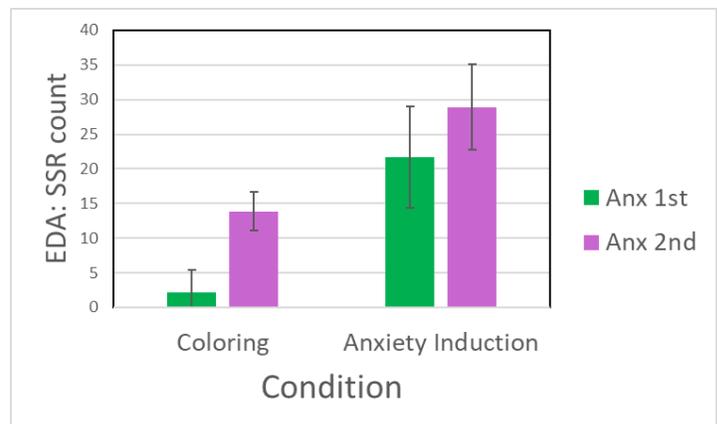

Figure 3. More skin conductance responses were identified during the anxiety induction compared to the coloring manipulation regardless of task order.

overall susceptibility to become anxious [10]. The trait portion also included 20 questions rated on the same 4-point scale. One-half indicated anxiety (e.g., I feel nervous and restless) and the other one-half were reverse scored to show lack of anxiety (e.g., I feel rested). Instructions guided participants to reflect on anxiety experienced over the past several months. An additional four items constructed by the experimenter asked participants to rate how stressed, how relaxed, how calm, and how anxious they were *right now in this moment* on a scale from 1 = *not at all* to 10 = *extremely*.

Results

The state portion of the STAI, additional anxiety ratings, and EDA were used to confirm that the anxiety induction manipulation actually caused anxiety to increase. For both self-report measures, a difference score was calculated by subtracting responses following the manipulation from responses prior to the manipulation. Higher scores, therefore, indicated that the manipulation increased perceived anxiety and lower scores indicated participants felt less anxiety following the manipulation. Analysis of EDA was based on the number of discrete skin conductance responses that occurred during the manipulation period.

Repeated measures ANOVA was used to test for anxiety changes due to the manipulation. Order was included as an independent variable since participants may have been naturally more anxious at the beginning of the study compared to the second manipulation. Analysis of data from the STAI showed a significant effect for manipulation, $F(1, 23) = 31.67$, $p < .001$, $\eta_p^2 = .58$, and a marginally significant interaction between manipulation and order, $F(1, 23) = 3.74$, $p < .07$, $\eta_p^2 = .14$. As shown in Figure 2, participants experienced a significant increase in anxiety after the anxiety induction ($M = 9.58$, $SD = 9.07$) and a decrease following the calming manipulation ($M = -3.08$, $SD = 6.24$). Ratings were exaggerated for participants who underwent anxiety induction before the first Go/NoGo task. Repeated measures analysis of the additional 4-item anxiety scale confirmed that anxiety was increased following anxiety induction ($M = 5.35$, $SD = 6.80$) and decreased following the coloring manipulation ($M = -2.96$, $SD = 4.38$).

Repeated measures ANOVA of skin conductance responses also confirmed that anxiety increased significantly following anxiety induction, $F(1, 22) = 12.44$, $p < .01$, $\eta_p^2 = .36$. As shown in Figure 3, participants averaged 22.48 ($SD = 20.82$) SCRs during the five minute anxiety induction period, but only 7.83 ($SD = 10.68$) during the calming manipulation.

Go/NoGo Accuracy

Go/NoGo accuracy was analyzed using a 2 (athlete or novice) by 2 (condition: anxiety induction or coloring) repeated measures ANCOVA. State anxiety and manipulation order were included as covariates. Analysis of errors made on the Go trials revealed a significant interaction between athletic status and condition, $F(1, 14) = 6.51$, $p = .02$, $\eta_p^2 = .32$. As shown in Figure 4, novices made more errors on Go trials after the anxiety induction manipulation compared to the calming manipulation, $t(5) = 2.64$, $p = .05$, but athletes did not differ significantly on errors following anxiety induction compared to the calming manipulation.

Analysis of errors made on the NoGo trials revealed a significant effect of task, $F(1, 15) = 8.05$, $p = .01$, $\eta_p^2 = .35$, and a significant interaction between task and order, $F(1, 15) = 16.06$, $p < .001$, $\eta_p^2 = .52$. As shown on Figure 5, there were more NoGo errors following anxiety induction only when the anxiety induction followed the calming manipulation.

P3 Amplitude and Latency

P3 amplitude was analyzed using a 2 (athlete or novice) by 2 (condition: anxiety induction or coloring) by 3 (electrode site: Fz, Cz, Pz) repeated measures ANOVA. Results indicated that there was a marginally significant interaction between athletic status, condition, and electrode site, $F(2, 20) = 3.04$, $p = .07$, $\eta_p^2 = .23$. The triple interaction was followed up with 2 (athlete or novice) by 2 (condition: anxiety induction or coloring) ANOVAs for each of the 3 sites. Analysis of Fz revealed a marginally significant interaction between athletic status and condition,
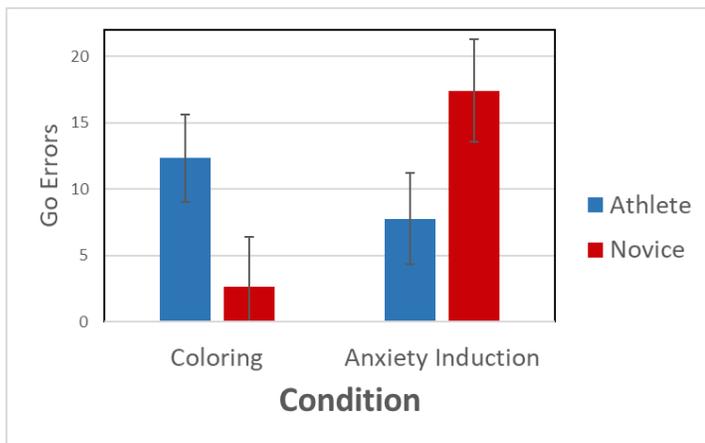
Figure 4. Novices made significantly more errors on Go trials after the anxiety induction manipulation compared to the calming manipulation, but athletes did not differ significantly on errors following anxiety induction compared to the calming manipulation.
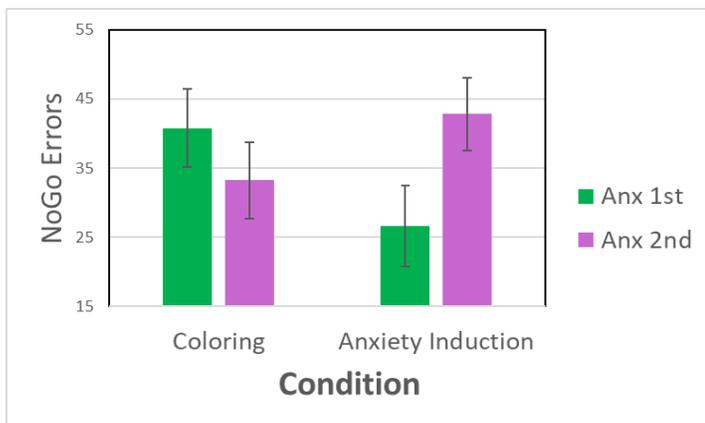

Figure 5. Fewer NoGo errors were made following anxiety induction when it was the first Go/NoGo task.

$F(1, 9) = 3.45$, $p = .10$, $\eta_p^2 = .28$. No effects were found for Cz or Pz locations, although means were in the same direction as means of Fz amplitudes. As shown in Figure 6, amplitude of the P3 at Fz was reduced for novices following anxiety induction, $t(5) = -5.06$, $p < .01$, but did not differ between conditions for athletes.

P3 latency was also analyzed using a 2 (athlete or novice) by 2 (condition: anxiety induction or coloring) by 3 (electrode site: Fz, Cz, Pz) repeated measures ANOVA. Results revealed a significant effect for electrode site, $F(2, 18) = 3.50$, $p = .05$, $\eta_p^2 = .28$, and a significant interaction between site and manipulation order, $F(2, 18) = 2.82$, $p = .04$, $\eta_p^2 = .30$. Since there were no significant effects for condition or athlete status, latencies were averaged over both Go/NoGo tasks for additional analyses. The significant location by order interaction was followed up with independent samples t tests for each electrode site based on condition order. Results showed that latencies were somewhat delayed for both Cz ($M = 455.80$, $SD = 27.23$ vs $M = 399.43$, $SD = 57.52$, $t(10) = 2.02$, $p = .07$) and Pz ($M = 444.60$, $SD = 42.91$ vs $M = 379.00$, $SD = 67.13$, $t(10) = 1.91$, $p = .09$) when the anxiety induction was first compared to when the coloring manipulation was first. Latencies for Fz did not differ based on condition order, $t(10) = -0.93$, $p = .38$.

Discussion

The most important findings of the current study were that novices made significantly more errors on the Go/NoGo task following anxiety induction and had reduced P3 amplitudes at the Fz site. In contrast, neither accuracy of athletes nor amplitudes of P3 differed significantly following the anxiety inducing or calming manipulations. The reduction
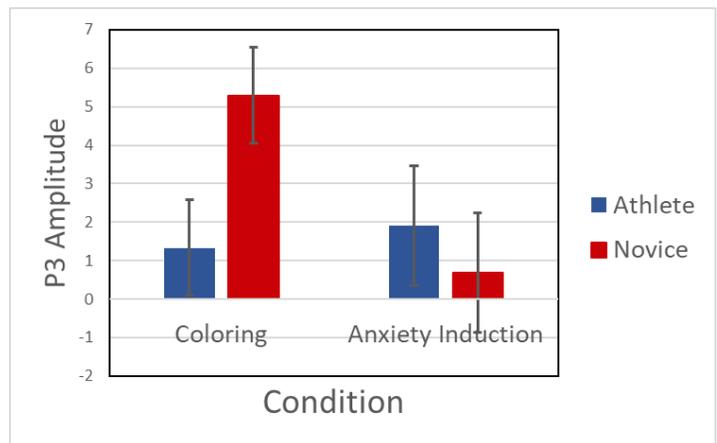

Figure 6. Amplitude of the P3 at Fz was reduced for novices following anxiety induction, but did not differ between conditions for athletes.

in amplitude over the prefrontal cortex for novices may be indicative of diminished ability to make and execute decisions in novices due to induced anxiety. These findings do not support the hypothesis, based on drive theory, that increased arousal associated with anxiety induction would improve performance. Participants performed either worse or no better in anxious conditions, meaning that anxiety was not interpreted as facilitative but instead had a debilitative effect. In contrast to drive theory [5], results support the findings of other studies that have noted increased anxiety associated with performance declines [9]. This evidence may suggest that anxiety does not always facilitate performance, and quite often it can do just the opposite.

However, the hypothesized difference between athletes and novices was supported by significant interactions between group and condition for both Go errors and P3 amplitude. Athletes were less negatively affected by the anxiety induction than novices. The similar performance of athletes following the anxiety induction and calming manipulations supports prior research that found athletes exhibited higher functional connectivity in areas related to motor and cognitive functions than novices [1, 8]. Due to extensive experience in high-stress environments like athletic training and competition, athletes may undergo cortical plasticity that produces greater functional connectivity and, in turn, more control over motor and cognitive functions. Consistent with prior research, there may be a difference in the way athletes and novices process information [8]. More experience and training in high-anxiety environments might leave athletes better equipped to perform in game-like situations under anxious conditions.

Although the order of the task manipulation was not a significant factor in analyses of Go errors or of P3 amplitude, order was important for NoGo errors. Analysis of accuracy on NoGo trials revealed an interaction between task performance and task order. When the coloring manipulation was the first conditional manipulation, both groups made more NoGo errors on the task following the anxiety induction. Conversely, when anxiety induction was the first conditional manipulation, both groups experienced more NoGo errors in the task following the coloring manipulation. This relationship may best be explained through a fatigue effect. The study as a whole lasted approximately 90 minutes, and each Go/NoGo task lasted approximately 20 minutes. It is probable that both athletes and novices began experiencing cognitive fatigue during the second Go/NoGo task simply due to its length. This cognitive fatigue may have been especially important for NoGo trials that required inhibition of habitual responses.

The difference in state anxiety levels before and after the manipulations, confirms that anxiety was successfully induced in participants using the 5-minute mental arithmetic task. This was further confirmed by the significant number of skin conductance responses recorded in EDA during the manipulation periods. Participants reported higher state anxiety levels when anxiety induction was the first manipulation, suggesting that participants may have been more anxious at the

beginning of the study, and that the level of anxiety tended to diminish over the course of the study.

Despite the strength of the anxiety induction manipulation in increasing anxiety, several limitations suggest findings should be interpreted cautiously. First, the sample size for P3 comparisons was quite small. Equipment malfunctions meant that the EEG recordings from several participants were not usable. In addition, data from a couple of high school athletes who were not current athletes was not used since they didn't meet criteria for either novices or current athletes. It is possible that with a larger sample the slight improvement of athletes following the anxiety manipulation might have reached significance.

A second limitation was the similarity in ERP data for Go and NoGo trials as shown in Figure 1. Typically, NoGo trials elicit a stronger P3 wave since the presentation of an infrequent stimuli requires updating the cognitive representation of the repetitive frequent stimuli. Less cognitive effort should be required to respond to the frequent stimuli, than the infrequently presented letters. In addition, inhibition of a response is believed to require more cognitive effort than engaging in a response, as anyone who played Simon Says as a child may recall. The strong P3 wave for Go trials found in the current study may reflect generation of a motoric response for these trials that was not needed for NoGo trials. It may also be due to engagement of working memory processes to recall the rules that require responses versus inhibition. Finally, the high frequency of Go trials means that the P3 was averaged over a greater number of trials and might be more reliable compared to the infrequently presented NoGo trials.

The length of the study was also a limitation, as seen by the fatigue effect experienced during the second task of each participant. Both athletes and novices, regardless of condition order, made more errors in the second task than the first, suggesting that the participants perhaps became fatigued or uninterested. Another issue with the length involved our ability to keep the participant in an anxious state the entire 20-minutes of the Go/NoGo task. Qi et al. (2018) used a model in which they re-established the anxious state after every few blocks to ensure that the participant remained anxious, and that is something that should be explored in a future study. Future research in this area should consider trying a shorter task or a re-induction of anxiety to retain anxious conditions and to combat the fatigue.

Despite these limitations, implications of the current study strongly suggest that individual differences based on athletic training and experience be considered in neuropsychological studies of anxiety and performance. Although demographic variables that include age, sex, and exposure to chemical substances are routinely screened for in related research, athletic status is rarely considered. The current results, however, suggest that anxiety may not be as detrimental for athletes as it is for novices in performance situations.

Acknowledgements

Notes and References

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