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Assessing Fear Responses With Event-Related Potential And Reaction Time In A Go-Nogo Task

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Abstract

Recent research indicates that mild traumatic brain injury patients respond faster to threat- than to non-threat stimuli and have impaired emotional attention. A student colleague also found faster responses to threat-related stimuli among football players than in controls. Employing a Go-NoGo task similar to that employed in these prior studies, the relationships between reaction times (RT), brain event-related potentials (ERPs), and emotion ratings for spider stimuli were examined. After viewing a clip from the movie *Arachnophobia*, twenty participants (12 male, 8 female) performed the Go-NoGo task in 4 blocks of 64 trials each, while 32 channels of electroencephalographic data were recorded. Each block assigned a different stimulus property as the Go signal -- a spider or a flower figure, or a green or red background. ERPLAB (plugin for EEGLAB software) measured the amplitude between N2-P3 ERP peaks. A moderate relationship for spider Go signals between peak Pz amplitude (midline parietal) and participants' post-experiment fear rating of the spider clip was found ($r = -0.41$, $p < 0.07$). The same relationship held true among flower ($r = -0.52$, $p < 0.02$) and green Go signals ($r = -0.48$, $p < 0.04$). For correct responses, self-reported spider fear on a pre-experiment questionnaire was positively correlated with RT for red ($r = .18$), green ($r = .47$), and flower stimuli ($r = 0.22$) but negatively correlated for spiders ($r = -0.28$). This contrasting correlation of fear ratings with RT was also found when post-experiment ratings of the movie clip were used, but was not found for incorrect trials (all correlations positive and ranging from 0.08 to 0.37). These ERP and RT findings indicate that brain responses in this experimental paradigm are influenced by fear of the Go stimulus and that rapid correct responding to the spider Go signal is specifically enhanced.

Keywords: EEG, Go-NoGo task, Fear assessment

1. Introduction

Recent studies have been attempting to address the effects and diagnostic measures of mild traumatic brain injuries (mTBIs), also known as concussions. The decision for an athlete to return to a sport after a concussion is based on symptomatology and cognitive performance, utilizing instruments such as the SCAT-3, with little to no direct knowledge of brain functionality[1]. Utilizing a Go-NoGo Task, it has been found that individuals with mTBIs have impairments in cognition and emotional attention[2].

The Go-NoGo task measures reaction time (RT) and requires multifaceted executive function abilities that are commonly used in everyday life[3]. Additionally, it is currently under analysis as a potential indicator for concussion diagnosis. Participants with mTBIs not only showed compromised performance on this task, but also had faster reaction times to emotionally relevant stimuli and, specifically, threat stimuli[2]. Gonzalez, our student colleague, also found similar results, indicating that football players reacted faster to threat- than to non-threat stimuli when compared to controls[3].

In a continuation of Gonzalez (2016)[3], this research examines cognitive and emotional effects on the Go-NoGo task. With the knowledge that patients with an mTBI have slower reaction times to the Go-NoGo task[4] and that, generally, attentional resources are given to emotion-related stimuli[5], it is possible that emotion-related stimuli would compromise the usage of the Go-NoGo task as a diagnostic tool for mTBIs. Unpublished research did conclude that there was a difference in reaction time within colors – green faster than red, within figures -- threat faster than non-threat stimuli, and between the two – color faster than figure[6]. Additionally, this was reflected in EEG recordings. As a follow-up of this unpublished work[6], the current study particularly focused on the addition of neurological response. The current study analyzes the differences in EEG and reaction time results when assessing an individual's perception of emotion-relevant and emotion-irrelevant stimuli outside of the context of mTBI or blows to the head.

2. Methodology

2.1 Participants

Participants were recruited from courses that were instructed by the psychology professors during the fall 2016 semester, with the incentive of extra credit in their respective courses. There was a total of twenty-one participants. Twelve of the participants were male and nine were female. One participant was excluded due to their hair impeding proper EEG recording.

2.2 Procedure

Participants would arrive in the laboratory during the allotted time period. After being assigned a participant number, an experimenter would send the "Neuropsychology Pre-Study Questionnaire" to their institution-given email address. Once completed on the lab computer station, the experimenter would check the individual's response to the "fear of spiders" scale. With responses greater than eight, the participant was asked if this fear pertained to image stimuli; if they responded "no", the experiment proceeded unhindered, if "yes" they would have been excluded from participation. However, there were no cases in which a participant's fear of spider stimuli was deemed extreme enough for exclusion.

To determine which EEG cap to be used, the large blue cap or the small red cap, experimenters measured the circumference of the participant's head. Once the cap was placed onto the participant's head, the Cz electrode was placed at the intersection of the midway point between the nasion and inion and the midway point between the two earlobes. Electrodes were placed on both the right and left mastoids, for reference channels. Two additional electrodes were placed on the left zygomatic bone, one lateral and one inferior to the eye to track eye movements. After fastening the chinstraps, electrode conductive gel was applied into each electrode fitting and each of the 32 electrodes were placed. Once any electronic devices were removed from the participant, they went into a sound-attenuated room, and the electrodes were attached to the AD box. They were instructed to keep both feet on the ground and move as little as possible, while positioned with comfortable access to the green and yellow buttons in front of them. Experimenters would go to the adjacent room and check the signal on the ActiView program[7]. Any abnormal signals would result in the questioned electrodes to be checked and more gel applied. After the experimenter read instructions, the participants completed a 32 trial practice round of the task and asked any questions. The experiment proceeded with a clip from the movie from *Arachnophobia*[8] and then the Go-NoGo task, which included 256 trials involving four blocks each with different conditions. A second questionnaire was completed at the end of the experiment.

Additional aspects of the procedure were a video on growth mindset[9] shown at the outset and a growth mindset inventory at the end. Since no evidence of growth mindset effects was found, these issues will not be further addressed in this paper.

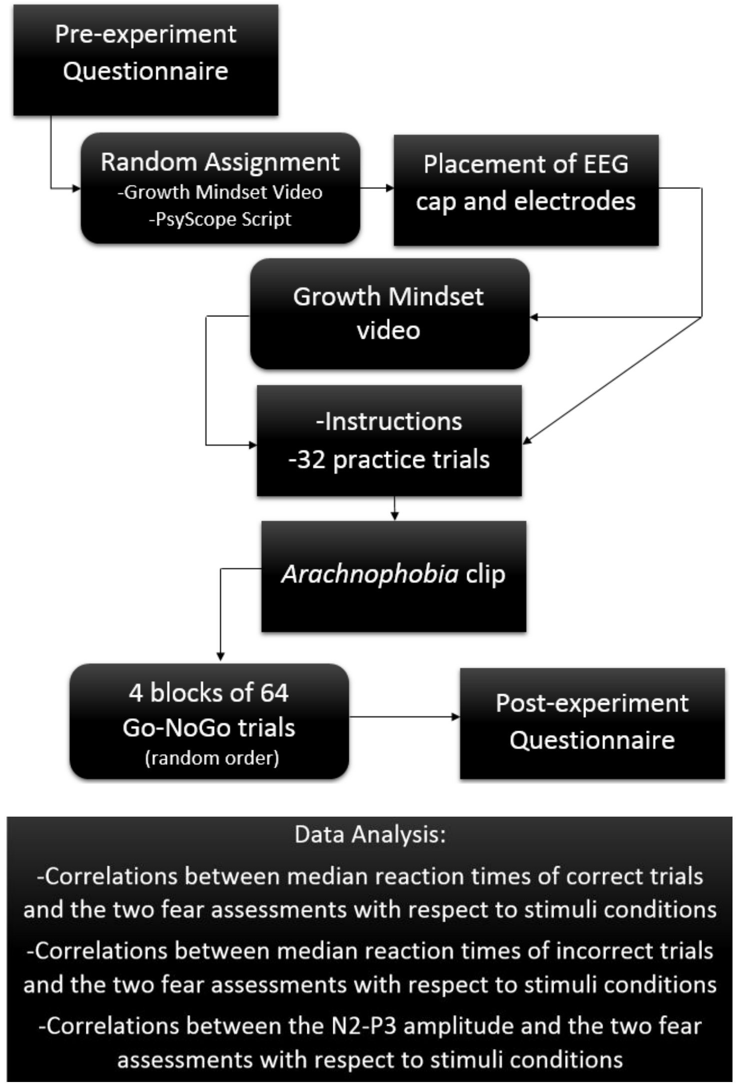

Figure 1. Procedure Outline

2.3 Instruments

Surveys were completed utilizing Google Forms. The pre-study questionnaire included demographics, such as age and grade classification, and a fear-of-spiders rating. The post-study survey was predominantly an inventory measuring grit, growth mindset, and self-efficacy. In conjunction with the inventory, questions were added to assess the perception of the *Arachnophobia* video, including questions such as "Please rate how scary you found the spider movie to be" with responses recorded on a Likert scale from 1 (not at all scary) to 10 (extremely scary).

The experiment was conducted using the open source program PsyScope X, Build 77[10] on a Macintosh computer to present stimuli. The button box (ioLab Systems) used provides timing accuracy to one millisecond. The ActiveTwo BioSemi system[7] was used to record EEG activity from 32 electrodes in the 10/20 system. EEGLAB[12] was used to process the data, while ERPLAB[13] was used to create event-related potentials (ERPs) for each participant. Lastly, R, Rcmdr, and RStudio were used for the statistical and graphical analysis of the data[14].

2.4 Go/NoGo task and EEG recordings

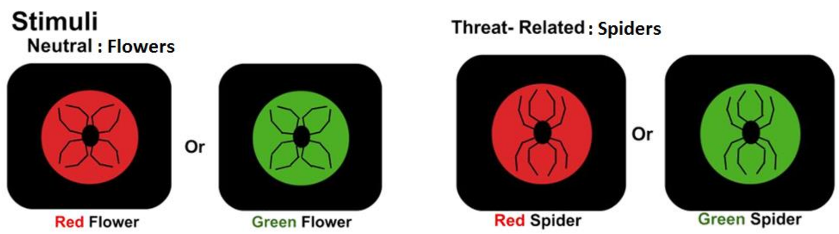

Figure 2. Examples of the stimuli

For this experiment, a Go-NoGo task was used to measure attention given to emotion relevant stimuli. A triangle, which was either oriented with the lone tip up or down, was followed by one of four stimuli, a picture of a red or green flower or a red or green spider (Figure 2). There were four blocks of 64 trials, half Go, half NoGo. Each block was governed by a different rule. The rules involved which stimuli was the Go condition, thus deciding what correct and incorrect responses are (Figure 3). Blocks 1 and 2 are known as emotion-irrelevant, due to color having no obvious emotional ties, while blocks 3 and 4 are considered emotion-relevant, since flowers and spiders contain valence in life. Yellow and green buttons were used to respond to the triangle being up or down, half of the participants had the yellow-up rule, and half had the yellow-down rule. See Figure 4 for a task example. A plug-in for EEGLAB, ERPLAB, was used to compile the EEG data in relation to the presentation of each stimulus, averaging similar trials[13]. Additionally, N2-P3 peak amplitude was measured using the Pz (midline parietal) electrode.

Blocks of 64 Trials	Go Signal (respond)	NoGo Signal (don't respond)
1: Emotion Irrelevant	**Red** (Flower or Spider)	**Green** (Flower or Spider)
2: Emotion Irrelevant	**Green** (Flower or Spider)	**Red** (Flower or Spider)
3: Emotion Relevant	**Flower** (Red or Green)	**Spider** (Red or Green)
4: Emotion Relevant	**Spider** (Red or Green)	**Flower** (Red or Green)

Figure 3. Blocks and corresponding conditions

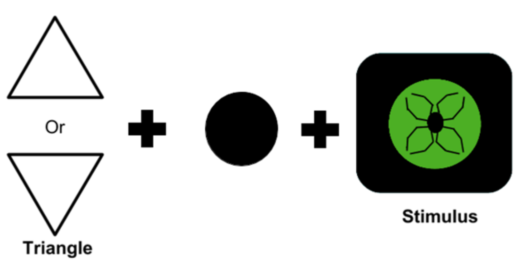

Figure 4. Task example

2.5 Bootstrapped 95% Confidence Intervals

As this study was a within-subjects design, bootstrapped 95% confidence intervals were created. These were to understand the effect size of the emotion-relevant and the emotion-irrelevant stimuli. Contrasts for the difference between emotion-relevant and emotion-irrelevant stimuli were created for both correct and incorrect responses. Bootstrapped 95% confidence intervals were run for each contrast. The correct response confidence interval had to be made by removing missing values. All bootstrapped confidence intervals were run using bootES[15] within RStudio[16]. Using this method replaces p-values, with more reliable confidence values and effect size.

3. Results

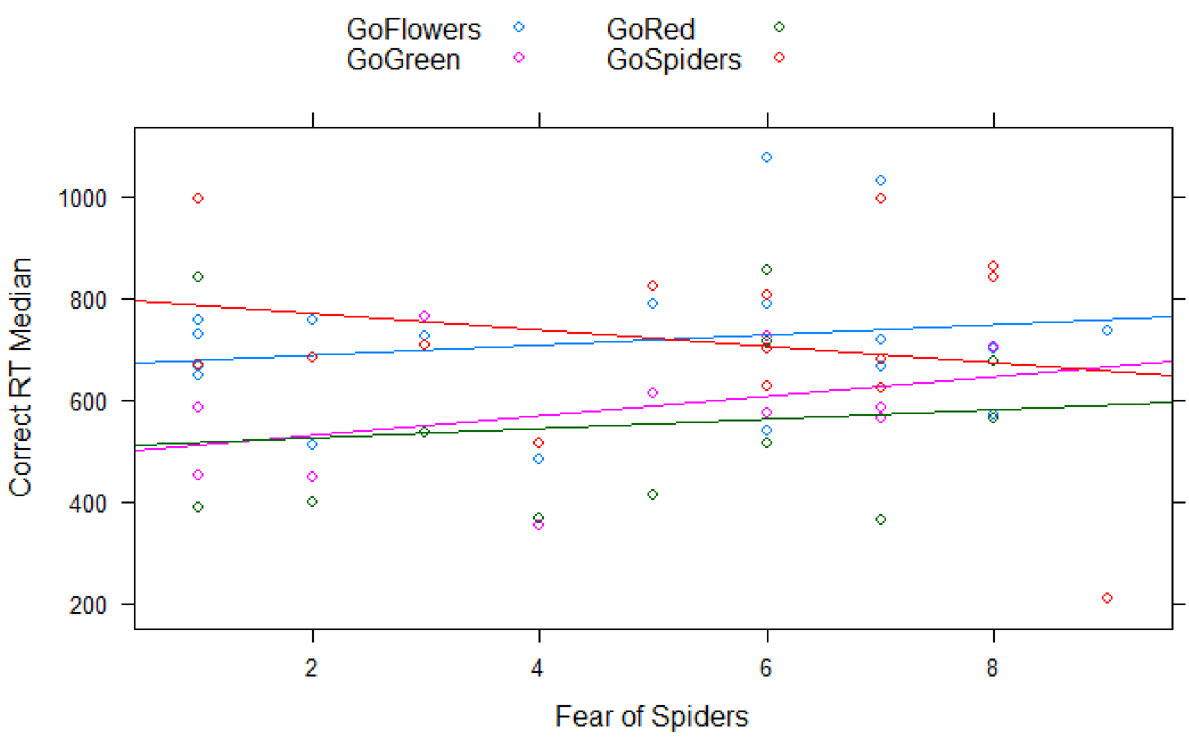

Figure 5. Scatterplot showing the various relationships between median correct RT and fear of spiders within each block.

In regards to correct responses, self-reported fear of spiders was positively correlated with RTs (red: r = 0.13, green: r = 0.39, flowers: r = 0.18), with the exception of the spiders bin (r = -0.22) (Figure 5). Thus, the data showed shorter RTs in regards to spider stimuli with higher levels of spider fear. Similar results occurred in regards to the scariness rating of *Arachnophobia* clip. For red and green trials, the more afraid participants were of the video, the longer their RT (red: r = 0.16, green: r = 0.24). Flower trials and RT had a small negative correlation (r = -0.11) and RT for spider trials correlated negatively with fear of the video clip (r = -0.21) (Figure 6), again showing a decrease in RT with higher fear of the video when presented with spider stimuli.

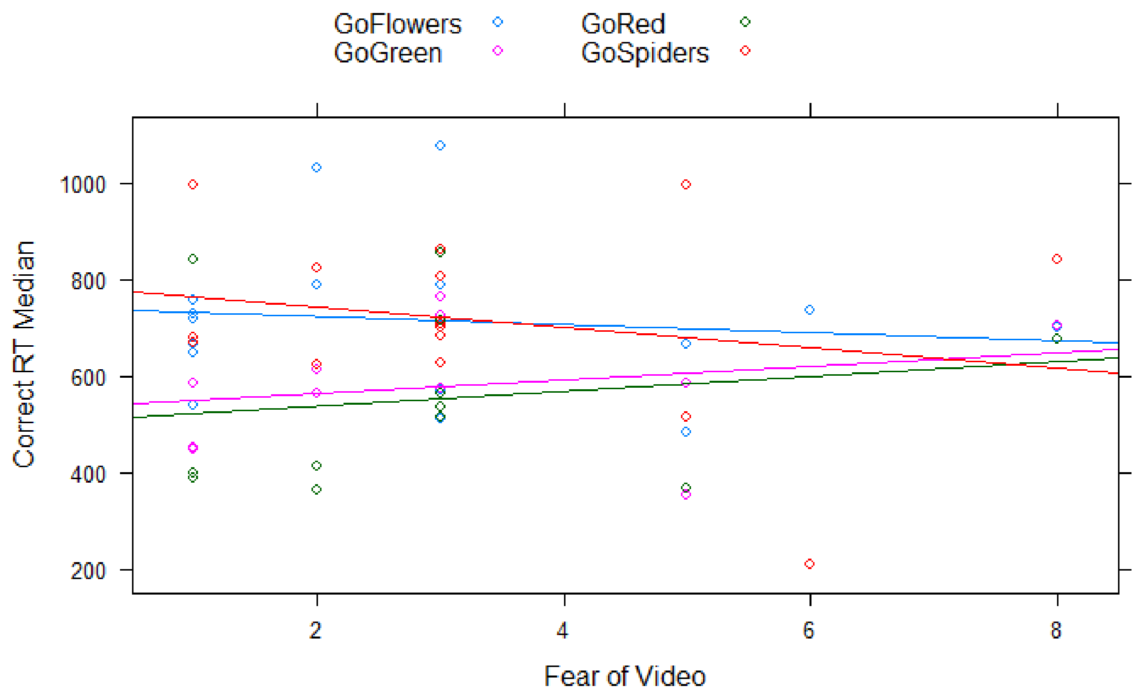

Figure 6. Scatterplot showing the various relationships between median correct RT and fear of the video within each block.

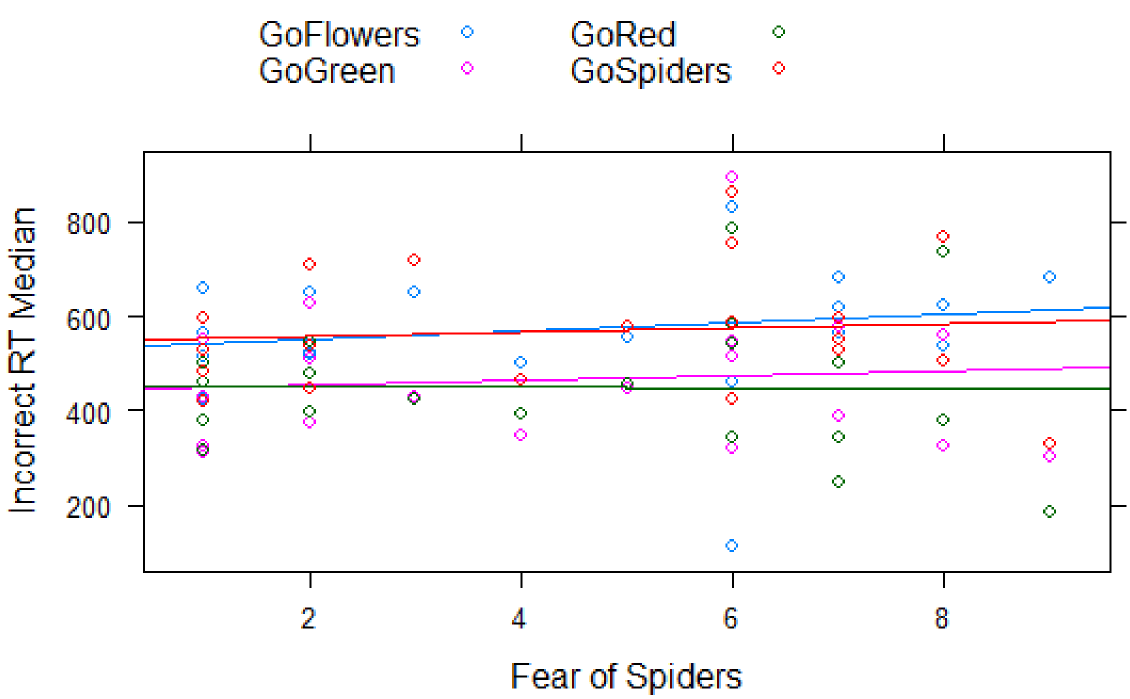

Figure 7. Scatterplot showing the positive relationships between median incorrect RT and fear of spiders with regard to block.

These results for correct responses were not replicated for incorrect responses. In relation to spider fear, RTs had a minor positive correlation (green: r = 0.09, flower: r = 0.16, and spider: r = 0.08), except red which had nearly no correlation, r = -0.004 (Figure 7). Thus, for each bin it took longer for participants to respond with higher levels of fear of spiders. Incorrect RTs also correlated positively with fear of the spider video (red: r = 0.30, green: r = 0.11, flower: r = 0.14, and spider: r = 0.16) (Figure 8).

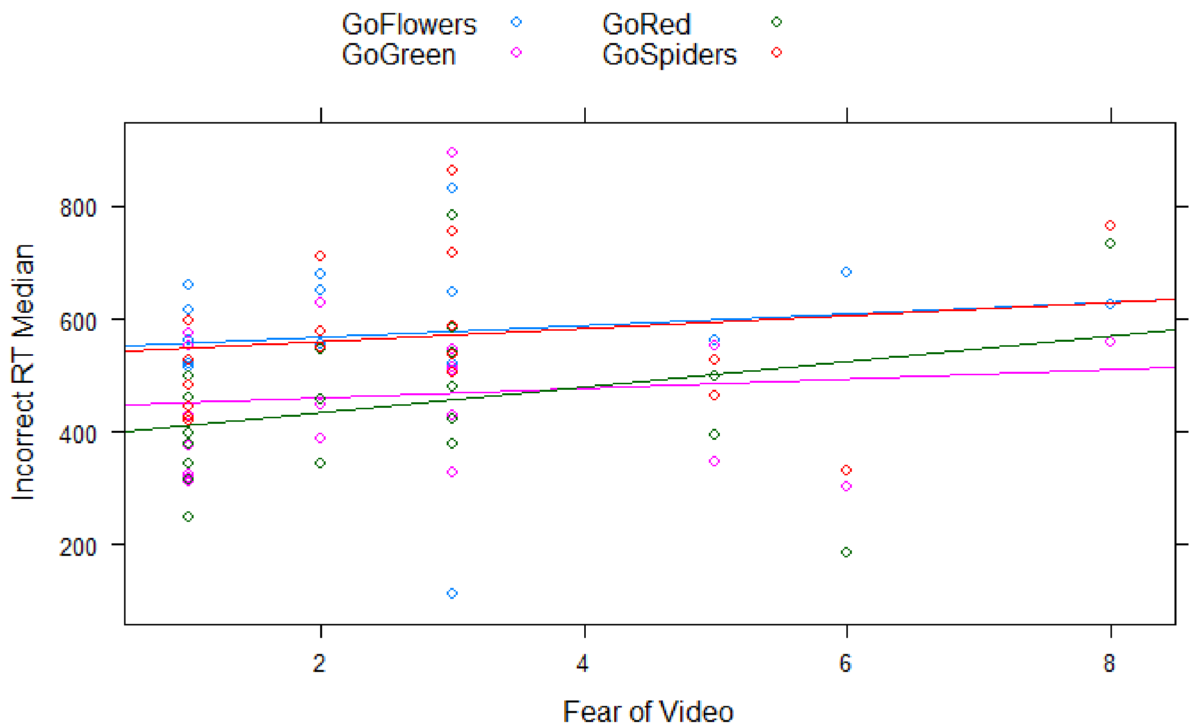

Figure 8. Scatterplot showing the positive relationships between median incorrect RT and fear of the spider video with regards to block.

A moderate relationship was found for the spider block between N2-P3 amplitude and participants' fear rating of the spider-movie clip (r = -0.41). In addition, this relationship was also found among the flower signals (r = -0.52), green signals (r = -0.48), and red signals (r = -0.28). These relationships are represented in Figure 9.

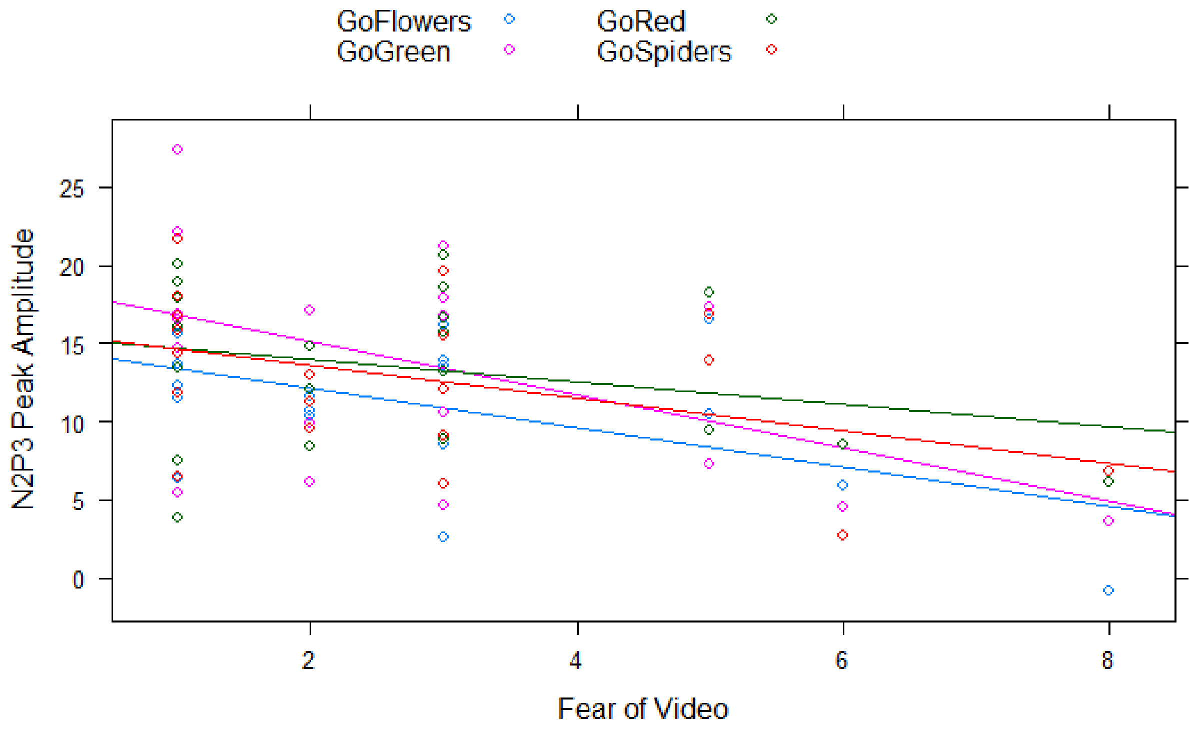

Figure 9. Scatterplots showing the negative relationships between N2-P3 peak amplitude and fear of the spider video with regards to block.

Bootstrapped 95% confidence intervals were found in regards to correct and incorrect reaction times. Correct reaction time had a mean difference of 169.9, 95% CI: [85.6 279.1], and a standard error of 47.3, while incorrect reaction times had a mean difference of 114.0, 95% CI: [74.0, 154.9], and a standard error of 20.7. Emotion- irrelevant stimuli (red and green) have faster reaction times than emotion-relevant stimuli (flowers and spiders). Note that the difference is probably larger than 100 milliseconds.

4. Discussion

Correct response reaction time data indicate that trials in which the rule pertains to spider stimuli might have been inducing a fear response, or causing individuals to react as if the stimuli were a threat. This conclusion is suggested by the fact that the only block that had a negative correlation with fear of spiders regarded spider stimuli. In regards to fear of spiders, participants responded faster to spider stimuli as their self-reported fear increased, which is the opposite pattern from the other blocks, indicating that while fear of the stimuli increases the speed of response for spider stimuli, that fear slows responses for other stimuli. Fear of the clip seemed to have a similar pattern. Spider stimuli elicited a negative correlation with reaction time decreasing with increased fear of the clip, while green and red had the reverse pattern. Flower stimuli had virtually no correlation with fear of the spider clip. These findings suggest that spider stimuli may be more susceptible to potential threat assessment. Potentially, this could indicate that individuals with higher fear of the clip were more capable of identifying emotion-relevant stimuli, and those with higher fear of spiders were more adept at identifying spider stimuli, or threat stimuli.

In relation to the incorrect trials, these analyses are interesting because, when the participants could not identify the threat, they responded similarly to both threat and non-threat stimuli. Thus, when the two figures could not be distinguished, reaction times remained consistent with the pattern shown by the colors, increasing reaction time with increasing fear of video and spiders.

The relationship between N2-P3 amplitude and fear of the spider clip shows an interesting moderate relationship, potentially indicating that amplitudes, non-specific to stimuli, are lower when participants are more afraid of the clip. Perhaps when participants are afraid of the clip, they are on constant threat alert, regardless of stimuli, indicating that the video clip had a lasting neurological effect. These ERP and reaction time findings imply that brain responses in this experimental paradigm are influenced by fear of the Go stimulus and that rapid correct responding to the spider Go signal is specifically enhanced.

The bootstrapping analysis revealed that reaction times were longer when participants were presented with emotion-relevant stimuli as opposed to emotion-irrelevant stimuli. This finding indicates that the emotion-relevant stimuli took more time to process than the emotion-irrelevant stimuli. This result may occur because the responses to emotion-irrelevant colors were automatized, since red and green are typically interpreted as stop and go signals. It may be that when emotion-relevant stimuli are presented, they take up more cognitive resources.

Studies like this could be the start of understanding fear responses to certain stimuli at a neurological level, while simultaneously perfecting techniques within the Go-NoGo task to be used as a concussion measurement tool. In future studies, a larger sample size would yield more reliable results, particularly with the addition of a control group – one that would not watch the video clip. More work should be done to enhance the understanding of what EEG recordings are actually revealing. Additionally, to understand more about the effects of the types of stimuli presented, colors with less automatized responses should be used and an emotion-irrelevant figures condition should be made, consisting of neutral shapes. Lastly, it would be interesting to look at both stimulus locked and response locked ERPs, as well as how they are related to the reactions times, peaks, and latencies.

5. Conclusions

Several possible conclusions can be proposed from these results. First, participants had faster reaction times when they report higher fear of spider stimuli in conjunction with being instructed to focus on a spider figure. This includes self-reported fear of spider stimuli in general, as well as fear of the clip from the movie *Arachnophobia*. When the rule pertains to the other stimuli, there is no correlation between fear and reaction time. This phenomenon only occurs when participants are able to correctly identify the stimuli, and respond appropriately according to the rule. Trials in which participants made errors, reaction times did not correlate negatively with fear of spider stimuli. Second, participants with high self-reported fear of spiders tend to have longer reaction times when the rules do not pertain to the spider figure. Once again, this is repeated with fear of general spiders as well as fear of the movie clip shown. Third, participants exhibited lower N2-P3 peak amplitudes when they reported high levels of fear of the movie clip. This effect was seen regardless of what rule was in place. It is possible that fear of the movie clip resulted in a lasting neurological effect of lower peak amplitudes. However, further research is needed to establish causation or directionality of this correlation. Fourth, participants took longer to respond to emotion-relevant stimuli than to emotion-irrelevant stimuli.

These conclusions give insight to what could be done to improve the Go-NoGo task as an mTBI assessment tool. For this application, it is necessary to have more knowledge of the behavioral and cognitive effects of context since what happens before they enter into the task could affect their performance. Additionally, the effects of different stimuli should be better understood, including the automatization and cultural associations of color, as well as figure associations.

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