THE UNIVERSITY OF CHICAGO

Effects of childhood trauma on the amplitude of P300 ERP response

By

Everett Goist

A paper submitted in partial fulfillment of the requirements for the Master of Arts degree in the

Master of Arts Program in the Social Sciences

Faculty Advisor: Royce Lee, MD

Preceptor: Hannah Hamilton, PhD

July 21, 2023

Abstract

This event-related potential (ERP) study examines the relationship between prevalence and severity of childhood trauma on the P300 ERP in medial electrodes (Fz, Pz, Cz). Initial analysis of the participants evaluated how amplitude and latency differ due to the frequency and expression of specific emotional faces (angry and neutral). Rarely occurring stimuli and angry faces resulted in higher amplitude P300 ERPs on average compared to frequently occurring stimuli and neutral faces. Childhood trauma was found to have no significant effect overall on the amplitude or latency of P300 ERP. This leads to further questioning about the effect of latency since maltreatment, beginning age of maltreatment, and the effect of therapies between the time of maltreatment and participation in this study.

Key words: EEG, ERP, P300, Oddball Paradigm, Ekman’s Faces, Childhood trauma

Word Count: 131 words

Acknowledgements

I would like to thank the University of Chicago Department of Psychology for accepting me into the Master of the Arts Program in Social Sciences and providing me the opportunity to grow my network, improve my repertoire as a researcher, and have the space to write my first publication. I would like to thank Dr. Hannah Hamilton for not only being a guide throughout my entire year but also a fantastic professor. Without her, I doubt I would have found a research PI in time or had the courage to submit anything master's thesis related. I appreciate her openness to criticism, as well as the quality of constructive criticism I received in turn. I would like to thank the Department of the Biological Sciences Division for accepting me as a researcher under the guidance of Dr. Royce Lee. I would like to thank Dr. Royce Lee for accepting and guiding me as a research assistant and not only guiding me through learning how to read and understand EEGs, but also some of the software used to process and analyze them. Additionally, I would like to thank him for guiding me in not only writing a master's thesis, but also how it will vary from professional publications so that I can be better prepared in the future. I would like to thank Abigail Spencer for her assistance throughout the entire project, as she undertook more than her fair share of troubleshooting, tutorial creating, and reminding. I am thankful that I had her as a research partner and that we could work collaboratively, and both produce meaningful research in the end. Finally, related to research, I would like to thank the software developers of EEGLab and ERPLab, Lopez-Calderon and Luck, as without their program, I doubt my research would have gone as smoothly. While I was quite tired of running both interfaces after all the files were processed and analyzed, the UIs were well crafted and regularly updated, ensuring my research success.

<u>**Effects of childhood trauma on the amplitude of P300 ERP response**</u>

We face a crisis of child welfare where about half of American children have adverse childhood experiences (ACEs) by the age of 17 (NICHQ, 2021, McLaughlin et al., 2020). These experiences can range from neglect to abuse, as well as witnessing traumatic events or others being abused. As these ACEs accrue, there is an increased likelihood for the development of both internalizing and externalizing pathologies, including generalized anxiety disorder, attention deficit hyperreactivity disorder, schizophrenia, and borderline personality disorder, among others (Cui et al., 2021, Quide et al., 2021, McLaughlin et al., 2020). In addition to psychopathological developments, ACEs can contribute to social-emotional processing deficits that last into adulthood, leading to an interest in the P300 wave, an event-related potential (ERP) often implicated in emotional processing and attention (Lahat et al., 2018, Howells et al., 2012, Cui et al., 2021, Quide et al., 2021).

Research Focus

This study aims to further examine the relationship between the severity of childhood trauma and its effect on social processing by examining its relationship to the P300 ERP in medial electrodes. This study utilizes an emotional discrimination task using a sample of photos from the Ekman's faces series via Oddball Paradigm to examine how neural activation may be related to the severity of childhood trauma, measured using the Childhood Trauma Questionnaire (CTQ). The P300 signal was chosen due to its commonly studied connection to emotional processing, especially in studies with participants with a past of ACEs and maltreated children (Pollak et al., 1997, Cui et al., 2022, Cui et al., 2021). The Oddball Paradigm is a frequently used method in brain-interface studies, such as EEG and ERP studies, to examine the neural processing of several types of auditory, semantic, and visual stimuli, including novel and emotional stimuli. The Oddball Paradigm is typically constructed using a 3:1 ratio of frequent to rare stimuli, where the participant is told to attend to or identify the rare condition (Kropotov, 2009). This study uses visual emotional stimuli in the form of facial photos from Ekman's photo series. The facial emotional discrimination task used in this study used rare angry and neutral faces to measure activation of a threat detection loop (Beyer et al., 2014; Denefrio et al., 2019;; Pfaltz et al., 2019; Yoon & Zinbarg, 2008).

Childhood Trauma and Measurement

Childhood trauma can result from a myriad of experiences, whether firsthand or observed, systemic or individual, direct in the form of abuse or indirect in the form of neglect. Childhood trauma has been found to be related to increased threat detection, accelerated biological aging, and misclassification of social emotional cues (McLaughlin et al., 2020). Based on developmental theories, these effects are largely adaptive during childhood, often allowing for faster identification of danger and improved self-reliability to improve survival and wellness. It is these adaptations that we examine in mature adults in this study, in the form of P300 peaks.

Childhood trauma is commonly measured using variations of the Childhood Trauma Questionnaire, or CTQ, originally developed by Bernstein and Fink, 1998. One of the most frequently administered variations is the CTQ-28, a 28-question version of the questionnaire introduced by Berstein et al., 2003, which has a total of 5 items per subdomain examined, consisting of physical abuse, physical neglect, emotional abuse, emotional neglect, and sexual abuse. The remaining 3 questions are to measure minimization to calculate the effects of denial. All CTQ questions are answered using a 5-point Likert Scale, ranging from 1 (Never True) to 5 (Very Often True). Examples of CTQ-28 questions are as follows: For physical abuse, "When I was growing up, people in my family hit me so hard that it left me with bruises or marks," for physical neglect, “When I was growing up, I didn't have enough to eat,” for emotional abuse, “When I was growing up, I thought that my parents wished I had never been born,” for emotional neglect, “When I was growing up, I felt loved,” and for minimalization/denial, “When I was growing up, I had the perfect childhood.” The CTQ-28 was chosen for its reliability to the original material while reducing the load on the participant. It is worth noting that by nature, the CTQ is a retrospective self-report survey and may be contaminated by childhood amnesia (Bernstein et al., 2003)

P300 Amplitude and its Significance

The P300 peak is a frequently studied component in event-related potential (ERP) studies, occurring between 300 to 800 milliseconds after the onset of a stimulus (Cui et al., 2021). Studies often examine the P300 ERP in two parts, P3a and P3b, where P3a is an earlier occurring peak because of novel stimuli, such as rarely seen stimuli during an oddball task. For this study, the waveform will be simply referred to as P300. It has been found to have a role in emotional processing, attention, contextual processing, and arousal (Pollak et al., 1997, Lee et al., 2017, Cui et al., 2021). Furthermore, relating to this study, facial imagery has been found to elicit a greater P300 response than neutral or non-facial stimuli (Zhao et al., 2013). In a maltreated child sample, it has been found that the amplitude of the P300 increased when the participants attended to angry faces, compared to their control counterparts who had no history of maltreatment (Pollak et al., 1997). Finally, P300 amplitude in response to novel auditory stimuli was found to partially mediate the association between physical abuse and externalizing behavior in children (Cui et al., 2021). This study will further add to the literature by evaluating the longevity of the effects of ACEs on P300 activity, as well as examining any relationships between certain subdomains of childhood trauma and P300 peak amplitude.

Current Study

The current study seeks to parse out the relationship between the types and severity of childhood trauma and neural processing of emotional faces, as measured by the P300 amplitude. I hypothesize that correlations will be found between overall CTQ scores and the P300 amplitude during the rare conditions. Additionally, I hypothesize that angry conditions will yield faster and higher P300 peaks than the neutral condition as abuse scores increase. Contributing to the literature in this form will help identify the greatest risk factors in terms of subdomains, defined by the CTQ, to psychopathologies not only in childhood and adolescence, but also maturity. Additionally, this research will help quantify the degree to which childhood trauma overall affects P300 ERP amplitude. This research contributes to identifying populations most at risk and implementing appropriate protective factors to prevent later issues and pathologies.

Method

Participants

Participants were recruited in the greater Chicago area using advertising stationed in public transportation and community centers. Inclusion criteria for participants consisted of anyone over the age of 18, right-handed, and meeting specific diagnostic criteria for either being a healthy control, having a personality disorder, having obsessive compulsive disorder, or possessing a psychiatric control (major depressive or anxiety) disorder. Exclusion criteria consisted of those with moderate to severe traumatic brain injuries, neurological disorders, and current or lifetime history of a psychotic or bipolar affective disorder.

Materials and Measures

All participants provided written informed consent using consent forms approved by the IRB of the Biological Sciences Division at the University of Chicago. All consenting participants were assigned a randomized identification number for anonymity, and affiliated demographic information was codified to ensure participant privacy. All data, including completion of the consent form, demographic information, CTQ-28 scores, and EEG study files were catalogued and stored via the participant ID on secure password protected servers. EEG data was collected using a 128-sintered Ag/AgCl active electrode head cap (ActiveTwo™ system, BioSemi B.V., Amsterdam) with no reference electrodes on a PC workstationA second networked workstation was used for the presentation of visual stimuli using Presentation software during the Oddball Paradigm.

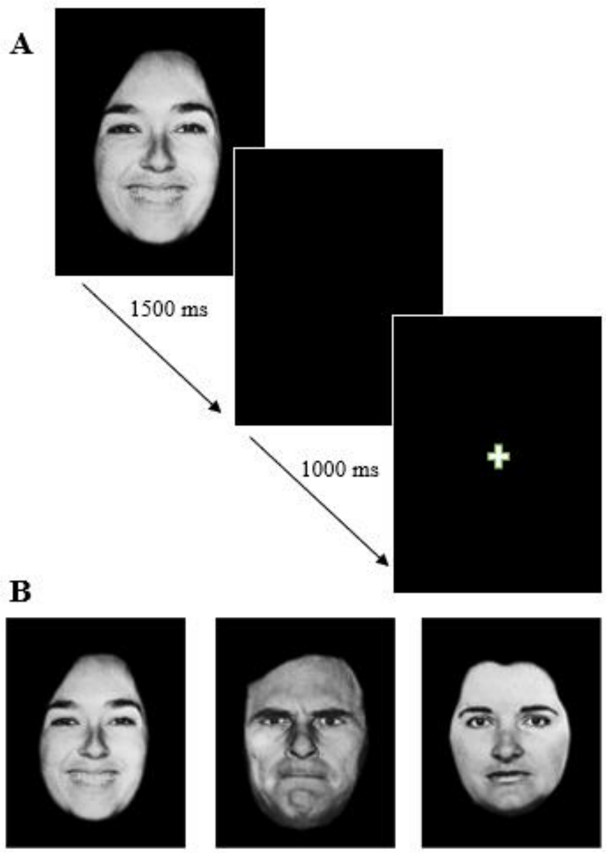
Procedure

Participants were prepared with the 128 active electrode head cap in a sound shielded testing room within the University of Chicago Medical Center, Department of Psychiatry and Behavioral Neuroscience. In the EEG task, subjects viewed visual stimuli derived from the Ekman series of photographs of models expressing the emotions Happy, Neutral, or Angry. This task consisted of two blocks both of which followed the classic oddball format with common happy faces interspersed with rare neutral or angry faces in a 3:1 ratio. The rare faces were either all neutral or all angry depending on the block. Between each face stimulus, a central fixation point was displayed to maintain eye fixation and minimize the need for large eye movements when face stimuli were presented. Block order was randomized and counterbalanced across participants. Participants were instructed to press the left button if they observed a happy face and the right button if they observed a non-happy face. Incorrect behavioral responses were discarded. Stimuli were displayed on a computer screen for 1500 ms, followed by a blank screen for 1000ms, followed by a fixation cross for 1,000 ms (see Figure 1). A total of 320 face stimuli were presented. All images were selected from a standard set of pictures of facial affect (Eckman

& Friesen, 1976). The frequent and rare images were from the same 2 models and were matched across rare angry and rare neutral blocks. The total task length was 15 minutes.

Figure 1

Emotional faces paradigm.



Note: Stimuli were displayed for 1500ms followed by a blank screen for 1000ms followed by fixation cross for 1000ms.

Statistical Analysis

EEG files were processed in MATLAB via the EEGLAB plugin (Lopez-Calderon & Luck, 2014) after conversion from the Biosemi formatted data. All files were assigned channel locations via a standardized channel location file, re-referenced to average, had a low-pass filter of .5hz applied, and resampled from 1024 Hz to 512 Hz. Large amplitude periods of EEG artifacts were rejected following visual identification, with as few trials removed from the dataset as possible. Channels behaving erratically were interpolated conservatively, removing only the timespans required. Unsupervised machine learning in the form of Independent Component Analysis (ICA) was then utilized to classify signaling into brain and non-brain sources such as eyeblinks, electronic noise, muscle artifact, and EKG. To reduce compute time, an EEG plugin was deployed, Preconditioned ICA for Real Data (PICARD), which preconditions the data with empirically derived priors (Ablin et al., 2018) Component removal was done using a 35% threshold of noise to brain signaling to retain the most relevant neural activity recorded.

After component removal, files were then ported to ERPLAB to restrain the timeframes to the condition trials of interest and more closely analyze the ERPs. All files had matching conditional event list files loaded to identify the trials of interest. BINLISTs were then created according to the conditional criteria (e.g., BINLIST describing Angry condition timepoints to the Angry condition test) for the program to identify the temporal position of the trials. Data was then epoched, removing timeframes unrelated to the conditional trials, then average ERPs were computed to create an overall peak per participant, per condition, and per electrode. For P300 ERPs, Fz, Cz, and Pz electrodes were selected for analysis. As a final step prior to export, all files were filtered using a 15hz low-pass filter in ERPLAB to smooth the P300 waveform resulting in a cumulative .5:15hz band-pass filter. The 15hz high-pass filter was advised by Bougrain et al. (2012) in their statistical analysis of what filters for P300 signaling preserve the most signal while removing the most noise. All ERP amplitudes and latencies were then exported to a text file and populated into SPSS and Microsoft Excel for visualization and analysis.

Results

Subjects

Of 67 participants, 64 had CTQ questionnaires completed. After preliminary analysis of ERP values, 1 participant was removed from the data pool due to outlier values. The remaining participants (N=63) sex, race, and history of psychiatric disorders could not be reported at the time due to lack of decoder. Table 1 depicts the CTQ scores of the sample.

Table 1

Descriptive Statistics of Sample CTQ 28 Scores

	N	Minimum	Maximum	*M*	*SD*
Childhood Trauma Questionnaire Total	63	25	74	37.59	10.95
All Abuse	63	15	48	21.71	7.42
All Neglect	63	10	38	15.87	5.537
Physical Abuse	63	5	15	7.06	2.51
Emotional Abuse	63	5	17	8.19	3.51
Physical Neglect	63	5	13	6.40	2.13
Emotional Neglect	63	5	25	9.49	4.16
Sexual Abuse	63	5	22	6.46	3.63

ERP

Table 2 depicts the descriptive statistics of the averaged P300 ERP amplitudes for each condition and conditional frequency. Rarely appearing emotional faces yielded greater average peak amplitudes, whereas the difference in average amplitudes between the angry and neutral conditions are mixed.

Table 2

Descriptive Statistics of P300 Amplitudes

	N	Minimum	Maximum	*M*	*SD*
A1 Angry Rare	63	-.98	3.58	.93	1.00
A1 Angry Frequent	63	-.84	2.45	.44	.65
C21 Angry Rare	63	-.96	5.20	1.05	1.15
C21 Angry Frequent	63	-1.24	4.38	.53	.98
A19 Angry Rare	63	-.91	4.38	1.02	.99
A19 Angry Frequent	63	-1.12	2.76	.56	.72
A1 Neutral Rare	63	-4.27	3.95	.67	1.10
A1 Neutral Frequent	63	-3.18	2.29	.37	.82
C21 Neutral Rare	63	-1.57	3.25	.82	.93
C21 Neutral Frequent	63	-1.47	2.90	.46	.79
A19 Neutral Rare	63	-.75	5.30	.98	1.18
A19 Neutral Frequent	63	-1.05	3.28	.59	.88

Table 3 presents the paired-samples t-tests of the P300 amplitudes. Significant findings are present for all frequency difference comparisons. A significant effect comparing emotional faces was only found in the A1 electrode during the rarely appearing faces. A Pearson's correlation was also calculated to examine the relationship between each pair in Table 3. There was a moderately positive correlation between the A1 rare and frequent angry faces, $r(61) = .534$, $p < .001$, as well as neutral faces, $r(61) = .671$, $p < .001$. At electrode C21, a moderately positive correlation was found between the rare and frequent presentations of angry faces, $r(61) = .684$, $p < .001$, and a weak correlation was found for the neutral faces $r(61) = .387$, $p < .001$. Similar to A1, the A19 electrode found moderately strong correlations between rare and frequent angry faces, $r(61) = .606$, $p < .001$, and neutral faces, $r(61) = .633$, $p < .001$. While controlling for frequency, a weak correlation was found between rarely occurring angry and neutral faces at the A1 electrode, $r(61) = .345$, $p = .003$, and the A19 electrode, $r(61) = .467$, $p < .001$. Contrary to the A electrodes, the only significant correlation found for C21 was very weakly positive, between frequently appearing neutral and angry faces, $r(61) = .266$, $p = .018$. Finally, a very weak positive correlation was also found at the A19 electrode between frequent angry and neutral faces, $r(61) = .215$, $p = .046$.

Table 3
Paired Samples Tests for P300 Amplitude

		Paired Differences							Significance	
					95% CI of the Difference				One-Sided	Two-Sided
		M	*SD*	*SE*	Lower	Upper	*t*	*df*	*p*	*p*
Pair 1	A1 Angry Rare - A1 Angry Freq	0.49	0.85	0.11	0.28	0.71	4.58	62	<.001	<.001
Pair 2	C21 Angry Rare - C21 Angry Freq	0.51	0.86	0.11	0.30	0.73	4.74	62	<.001	<.001
Pair 3	A19 Angry Rare - A19 Angry Freq	0.46	0.80	0.10	0.26	0.66	4.60	62	<.001	<.001
Pair 4	A1 Neutral Rare - A1 Neutral Freq	0.31	0.82	0.10	0.10	0.51	2.98	62	.002	.004
Pair 5	C21 Neutral Rare - C21Neutral Freq	0.36	0.96	0.12	0.12	0.60	2.97	62	.002	.004
Pair 6	A19 Neutral Rare - A19 Neutral Freq	0.39	0.92	0.12	0.16	0.62	3.36	62	<.001	.001
Pair 7	A1 Angry Rare - A1 Neutral Rare	0.26	1.20	0.15	-0.04	0.56	1.73	62	.045	.089
Pair 8	A1 Angry Freq - A1 Neutral Freq	0.08	0.95	0.12	-0.16	0.31	0.63	62	.265	.531
Pair 9	C21 Angry Rare - C21 Neutral Rare	0.22	1.37	0.17	-0.12	0.57	1.30	62	.099	.198
Pair 10	C21 Angry Freq - C21 Neutral Freq	0.07	1.09	0.14	-0.20	0.34	0.51	62	.305	.609
Pair 11	A19 Angry Rare - A19 Neutral Rare	0.04	1.13	0.14	-0.25	0.32	0.27	62	.396	.792
Pair 12	A19 Angry Freq - A19 Neutral Freq	-0.03	1.01	0.13	-0.29	0.22	-0.26	62	.398	.796

Table 4 provides descriptive statistics for the latency for each averaged P300 peak to occur.

Table 4

Descriptive Statistics of P300 Latency

	N	Minimum	Maximum	*M*	*SD*
A1 Angry Rare	63	416.02	699.22	561.26	87.04
A1 Angry Frequent	63	406.25	699.22	544.01	91.76
C21 Angry Rare	63	404.30	699.22	538.04	86.00
C21 Angry Frequent	63	408.20	697.27	561.97	89.27
A19 Angry Rare	63	408.20	693.36	559.00	95.68
A19 Angry Frequent	63	400.39	685.55	539.48	74.98
A1 Neutral Rare	63	402.34	689.45	534.97	98.51
A1 Neutral Frequent	63	400.39	699.22	539.43	102.79
C21 Neutral Rare	63	404.30	699.22	560.11	94.28
C21 Neutral Frequent	63	402.34	697.27	544.15	86.72
A19 Neutral Rare	63	414.06	699.22	550.94	88.53
A19 Neutral Frequent	63	410.16	699.22	556.14	94.15

Table 5 presents the paired samples test for the latency of P300 ERPs. No significant differences were found between the conditions. One significant very weak positive correlation was found in the neutral face condition at the A1 electrode between the rare and frequent occurrence rate, $r(61) = .268$, $p = .017$. All other correlations were non-significant with $p > .05$.

Table 5

Paired Samples Test for P300 Latency

		Paired Differences							Significance	
					95% CI of the Difference				One-Sided	Two-Sided
		M	*SD*	*SE*	Lower	Upper	*t*	*df*	*p*	*p*
Pair 1	A1 Angry Rare - A1 Angry Freq	17.25	137.29	17.30	-17.32	51.83	.997	62	.161	.322
Pair 2	C21 Angry Rare - C21 Angry Freq	-23.93	118.41	14.92	-53.75	5.89	-1.604	62	.057	.114
Pair 3	A19 Angry Rare - A19 Angry Freq	19.52	108.04	13.61	-7.69	46.73	1.434	62	.078	.157
Pair 4	A1 Neutral Rare - A1	-4.46	121.84	15.35	-35.15	26.22	-.291	62	.386	.772

	Neutral Freq									
Pair 5	C21 Neutral Rare - C21Neutral Freq	15.97	124.25	15.65	-15.33	47.26	1.020	62	.156	.312
Pair 6	A19 Neutral Rare - A19 Neutral Freq	-5.21	120.15	15.14	-35.47	25.05	-.344	62	.366	.732
Pair 7	A1 Angry Rare - A1 Neutral Rare	26.29	134.34	16.93	-7.54	60.12	1.553	62	.063	.125
Pair 8	A1 Angry Freq - A1 Neutral Freq	4.57	149.28	18.81	-33.02	42.17	.243	62	.404	.809
Pair 9	C21 Angry Rare - C21 Neutral Rare	-22.07	126.61	15.95	-53.96	9.81	-1.384	62	.086	.171
Pair 10	C21 Angry Freq - C21 Neutral Freq	17.83	127.93	16.12	-14.39	50.04	1.106	62	.136	.273
Pair 11	A19 Angry Rare - A19 Neutral Rare	558.02	95.67	12.05	533.92	582.11	46.294	62	<.001	<.001
Pair 12	A19 Angry Freq - A19 Neutral Freq	-16.66	114.43	14.42	-45.48	12.16	-1.156	62	.126	.252

Hypothesis Testing

Based on our hypothesis, a simple linear regression was performed to examine the relationship between severity and type of childhood trauma, and the resulting amplitude and latency of P300 peaks. Only two values calculated were found to have a $p < .05$, but as they were constants and the affiliated independent variables did not have any significance, no significance was found overall. No significant differences in P300 amplitude during the angry, nor neutral conditions were observed due to CTQ total score, total abuse score, or total neglect score. Additionally, no significant effects were predicted by total CTQ, total abuse, or total neglect scores when examining the difference in the frequent and rare condition amplitudes.

Table 6

Linear Regression of P300 Amplitude with Total Scores as Independent Variables

				95% CI			
DV	Model Components	Beta	*SE*	Lower	Upper	β	*P*
A1 Angry Rare	Constant	0.68	0.45	-0.22	1.59		1.51
	All Abuse	-0.02	0.02	-0.05	0.02	-0.13	-0.94
	All Neglect	0.04	0.02	-0.01	0.09	0.22	1.58
C21 Angry Rare	Constant	1.32	0.53	0.26	2.37		0.02*
	All Abuse	-0.03	0.02	-0.07	0.02	-0.18	0.20
	All Neglect	0.02	0.03	-0.04	0.08	0.10	0.46
A19 Angry Rare	Constant	1.21	0.45	0.30	2.11		0.01*
	All Abuse	-0.02	0.02	-0.06	0.02	-0.16	0.27
	All Neglect	0.02	0.03	-0.03	0.07	0.09	0.51
A1 Angry Frequent	Constant	-0.06	0.49	-1.05	0.93		0.90
	All Abuse	0.03	0.02	-0.01	0.08	0.23	0.10
	All Neglect	0.00	0.03	-0.05	0.06	0.00	0.99
C21 Angry Frequent	Constant	0.44	0.43	-0.42	1.29		0.31
	All Abuse	0.02	0.02	-0.02	0.05	0.15	0.31
	All Neglect	0.00	0.02	-0.05	0.05	0.00	0.98
A19 Angry Frequent	Constant	0.59	0.54	-0.50	1.67		0.28
	All Abuse	0.01	0.02	-0.03	0.06	0.08	0.59
	All Neglect	0.01	0.03	-0.05	0.07	0.04	0.79

Note: Linear regression performed where the independent variables were the total CTQ score, all abuse score, and all neglect scores.

To test the second hypothesis, ANOVA was performed to examine the difference of amplitude and latency between the angry and neutral conditions. No significant differences in amplitude or latency were observed because of total abuse, physical abuse, or emotional abuse.

Table 7

ANOVA of P300 Amplitude Differences Between Angry and Neutral Faces with Abuse Scores as Independent Variables

Comparison	Model		Sum of Squares	*df*	Mean Square	*F*	Sig.
A1 Rare Difference	1	Regression	8.75	3	2.92	2.131	.106[b]
		Residual	80.78	59	1.37		
		Total	89.53	62			
A1 Frequent Difference	1	Regression	2.07	3	0.69	0.760	.521[b]
		Residual	53.64	59	0.91		
		Total	55.71	62			
C21 Rare Difference	1	Regression	7.49	3	2.50	1.347	.268[b]
		Residual	109.38	59	1.85		
		Total	116.87	62			
C21 Frequent Difference	1	Regression	0.98	3	0.33	0.266	.849[b]
		Residual	72.12	59	1.22		
		Total	73.10	62			
A19 Rare Difference	1	Regression	4.12	3	1.37	1.077	.366[b]
		Residual	75.18	59	1.27		
		Total	79.30	62			
A19 Frequent Difference	1	Regression	0.09	3	0.03	0.029	.993[b]
		Residual	63.33	59	1.07		
		Total	63.43	62			

Table 8

ANOVA of P300 Latency Differences Between Angry and Neutral Faces with Abuse Scores as Independent Variables

Comparison	Model		Sum of Squares	*df*	Mean Square	*F*	Sig.
A1 Rare Difference	1	Regression	32108.33	3	10702.78	0.581	.630b
		Residual	1086863.29	59	18421.41		
		Total	1118971.61	62			
A1 Frequent Difference	1	Regression	144593.85	3	48197.95	2.299	.087b
		Residual	1237096.64	59	20967.74		
		Total	1381690.49	62			
C21 Rare Difference	1	Regression	42543.65	3	14181.22	0.88	.457b
		Residual	951264.97	59	16123.14		
		Total	993808.62	62			
C21 Frequent Difference	1	Regression	44272.46	3	14757.49	0.897	.448b
		Residual	970401.69	59	16447.49		
		Total	1014674.15	62			
A19 Rare Difference	1	Regression	14314.55	3	4771.52	0.34	.796b
		Residual	826959.75	59	14016.27		
		Total	841274.30	62			
A19 Frequent Difference	1	Regression	38612.63	3	12870.88	0.982	.407b
		Residual	773220.58	59	13105.43		
		Total	811833.21	62			

Discussion

Initial analysis of 63 participants from the greater Chicago area examined the correlations between the conditions and response from the participants in the form of peak amplitude and latency. Consistent to other literature, novel conditions resulted in significant positive correlations with amplitude (Pollak et al., 1997), but latency was not as affected. Where novel stimuli were seen to result in faster identification and therefore shorter ERP latencies in prior literature, it was not supported in the current study. This could allude to the participants not classifying the rare faces as entirely novel, whether because they still occurred at predictable intervals, or because faces are not necessarily as novel as other testing stimuli used in the literature. Additionally, the medial electrodes recorded on average higher amplitudes when angry faces were perceived regardless of frequency. This increased amplitude is likely mitigated by our threat detection pathway identifying angry faces as more important than neutral, and that more attention should be delegated to them. The frontal medial electrode, A19, was observed to respond similarly to frequent angry and neutral faces, suggesting an attentional role to frequently appearing non-positive emotional faces.

In the analysis of hypothesis 1, a positive relationship was expected to be found between CTQ composite scores and the amplitude of the P300 ERP during rare conditions. This hypothesis was not supported, leading to further conflict in the literature. Additionally, abuse was examined as the independent variable potentially leading to an increase in amplitude of P300 peaks in angry conditions and expediting response in comparison to neutral conditions. Neither of these components were supported, resulting in hypothesis 2 not being supported. The lack of support may have been the result of a skewed sample where the majority of the participants had little to no childhood maltreatment, resulting in low strength analysis of those with higher values. Additionally, a larger sample could have corrected the skew, as well as improved the analytical strength.

Limitations

This study was largely limited by the participant pool inhibiting the observance of a normal distribution of scores for the CTQ. Much of the sample expressed little to no abuse or neglect, countering the statistic of 50% of children experiencing childhood trauma (NICHQ, 2021, McLaughlin et al., 2020). Additionally, the year of maltreatment onset was not recorded, impairing the potential analysis of developmental period as a covariate. Future analysis should seek a larger dataset, as well as collecting when the participant's maltreatment began during childhood. Additionally, the sample should be separated into upper, lower, and middle groups defined by quartiles to allow for post-hoc analysis.

References

Ablin, P., Cardoso, J.-F., & Gramfort, A. (2018). Faster independent component analysis by preconditioning with Hessian approximations. *IEEE Transactions on Signal Processing*, *66*(15), 4040–4049. https://doi.org/10.1109/tsp.2018.2844203

Bernstein, D. P., Stein, J. A., Newcomb, M. D., Walker, E., Pogge, D., Ahluvalia, T., Stokes, J., Handelsman, L., Medrano, M., Desmond, D., & Zule, W. (2003). Development and validation of a brief screening version of the Childhood Trauma Questionnaire. *Child Abuse & Neglect*, 27(2), 169–190. https://doi.org/10.1016/s0145-2134(02)00541-0

Beyer, K., Kaltenbach, A., Szabo, A., Bogar, S., Nieto, F., & Malecki, K. (2014). Exposure to neighborhood green space and Mental Health: Evidence from the survey of the Health of Wisconsin. *International Journal of Environmental Research and Public Health*, *11*(3), 3453–3472. https://doi.org/10.3390/ijerph110303453

Bougrain, L., Saavedra, C., & Ranta, R. (2012). Finally, what is the best filter for P300 detection? *TOBI Workshop III - Tools for Brain-Computer Interaction*. https://doi.org/hal-00756669

Cui, N., Raine, A., Connolly, C. A., Richmond, T. S., Hanlon, A. L., McDonald, C. C., & Liu, J. (2021). P300 event-related potentials mediate the relationship between child physical abuse and externalizing behavior. *Frontiers in Psychology*, *12*(720094). https://doi.org/10.3389/fpsyg.2021.720094

Cui, N., Zlotnick, C., Li, Y., & Golfenshtein, N. (2022). Editorial: Childhood adversity and life-course consequences. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.967180

Denefrio, S., Myruski, S., Mennin, D., & Dennis-Tiwary, T. A. (2018). When neutral is not neutral: Neurophysiological evidence for reduced discrimination between aversive and non-aversive information in generalized anxiety disorder. *Motivation and Emotion*, *43*(2), 325–338. https://doi.org/10.1007/s11031-018-9732-0

Did you know childhood trauma affects nearly half of American children?. NICHQ. (2021, May 5). https://www.nichq.org/insight/bringing-trauma-forefront-early-childhood-systems

Ekman, P., & Friesen, W. V. (2003). *Unmasking the Face: A Guide to Recognizing Emotions From Facial Expressions.* Malor Books

Hart, H., & Rubia, K. (2012). Neuroimaging of child abuse: A critical review. *Frontiers in Human Neuroscience*, *6*. https://doi.org/10.3389/fnhum.2012.00052

Howells, F. M., Stein, D. J., & Russell, V. A. (2012). Childhood trauma is associated with altered cortical arousal: Insights from an EEG study. *Frontiers in Integrative Neuroscience, 6*. https://doi.org/10.3389/fnint.2012.00120

Keller, A. S., Ling, R., & Williams, L. M. (2021). Spatial attention impairments are characterized by specific electro-encephalographic correlates and partially mediate the association between early life stress and anxiety. *Cognitive, Affective, & Behavioral Neuroscience*, *22*(2), 414–428. https://doi.org/10.3758/s13415-021-00963-0

Kim, S., Kim, J. S., Jin, M. J., Im, C.-H., & Lee, S.-H. (2018). Dysfunctional frontal lobe activity during inhibitory tasks in individuals with childhood trauma: An event-related potential study. *NeuroImage: Clinical*, *17*, 935–942. https://doi.org/10.1016/j.nicl.2017.12.034

Klimova, A., Bryant, R. A., Williams, L. M., & Louise Felmingham, K. (2013). Dysregulation in cortical reactivity to emotional faces in PTSD patients with high dissociation symptoms. *European Journal of Psychotraumatology*, *4*(1). https://doi.org/10.3402/ejpt.v4i0.20430

Kluetsch, R. C., Ros, T., Théberge, J., Frewen, P. A., Calhoun, V. D., Schmahl, C., Jetly, R., & Lanius, R. A. (2013). Plastic modulation of PTSD resting-state networks and subjective wellbeing by EEG Neurofeedback. *Acta Psychiatrica Scandinavica*, *130*(2), 123–136. https://doi.org/10.1111/acps.12229

Kropotov, J. D. (2009). Chapter 15 - Methods: Neuronal Networks and Event-Related Potentials. In *Quantitative eeg, event-related potentials and neurotherapy* (pp. 325–365). essay, Elsevier/Academic.

Lahat, A., Tang, A., Tanaka, M., Van Lieshout, R. J., MacMillan, H. L., & Schmidt, L. A. (2018). Longitudinal associations among child maltreatment, resting frontal electroencephalogram asymmetry, and adolescent shyness. *Child Development*, *89*(3), 746–757. https://doi.org/10.1111/cdev.13060

Lee, S.-H., Park, Y., Jin, M. J., Lee, Y. J., & Hahn, S. W. (2017a). Childhood trauma associated with enhanced high frequency band powers and induced subjective inattention of adults. *Frontiers in Behavioral Neuroscience*, *11*(148), 1–12. https://doi.org/10.3389/fnbeh.2017.00148

Lee, S.-H., Park, Y., Jin, M. J., Lee, Y. J., & Hahn, S. W. (2017b). Childhood trauma associated with enhanced high frequency band powers and induced subjective inattention of adults. *Frontiers in Behavioral Neuroscience*, *11*. https://doi.org/10.3389/fnbeh.2017.00148

Liu, Y., Peng, H., Wu, J., & Duan, H. (2021). The relationship between childhood emotional abuse and processing of emotional facial expressions in healthy young men: Event-related potential and behavioral evidence. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.686529

Lopez-Calderon, J., & Luck, S. J. (2014). ERPLAB: An open-source toolbox for the analysis of event-related potentials. *Frontiers in Human Neuroscience*, *8*, 213. https://doi.org/10.3389/fnhum.2014.00213

MacNamara, A., Rabinak, C. A., Kennedy, A. E., & Phan, K. L. (2017). Convergence of fmri and ERP measures of emotional face processing in combat-exposed U. S. military veterans. *Psychophysiology*, *55*(2). https://doi.org/10.1111/psyp.12988

McLaughlin, K. A., Colich, N. L., Rodman, A. M., & Weissman, D. G. (2020). Mechanisms linking childhood trauma exposure and psychopathology: A transdiagnostic model of risk and resilience. *BMC Medicine*, *18*(1). https://doi.org/10.1186/s12916-020-01561-6

Pfaltz, M. C., Passardi, S., Auschra, B., Fares-Otero, N. E., Schnyder, U., & Peyk, P. (2019). Are you angry at me? negative interpretations of neutral facial expressions are linked to child maltreatment but not to posttraumatic stress disorder. *European Journal of Psychotraumatology*, *10*(1). https://doi.org/10.1080/20008198.2019.1682929

Pollak, S. D., Cicchetti, D., Klorman, R., & Brumaghim, J. T. (1997). Cognitive brain event-related potentials and emotion processing in maltreated children. *Child Development*, *68*(5), 773–787. https://doi.org/10.2307/1132032

Pollak, S. D., Klorman, R., Thatcher, J. E., & Cicchetti, D. (2001). P3b reflects maltreated children’s reactions to facial displays of emotion. *Psychophysiology*, *38*(2), 267–274. https://doi.org/10.1111/1469-8986.3820267

Quidé, Y., Girshkin, L., Watkeys, O. J., Carr, V. J., & Green, M. J. (2020). The relationship between cortisol reactivity and emotional brain function is differently moderated by childhood trauma, in bipolar disorder, schizophrenia and healthy individuals. *European*

Archives of Psychiatry and Clinical Neuroscience, *271*(6), 1089–1109. https://doi.org/10.1007/s00406-020-01190-3

Schauer, P. A., Rauh, J., Leicht, G., Andreou, C., & Mulert, C. (2019). Altered oscillatory responses to feedback in borderline personality disorder are linked to symptom severity. *Brain Topography*, *32*(3), 482–491. https://doi.org/10.1007/s10548-019-00700-4

Yoon, K. L., & Zinbarg, R. E. (2008). Interpreting neutral faces as threatening is a default mode for socially anxious individuals. *Journal of Abnormal Psychology*, *117*(3), 680–685. https://doi.org/10.1037/0021-843x.117.3.680

Zhao, Q., Zhang, Y., Onishi, A., & Cichocki, A. (2013). An affective BCI using multiple ERP components associated to facial emotion processing. *SpringerBriefs in Electrical and Computer Engineering*, 61–72. https://doi.org/10.1007/978-3-642-36083-1_7