Event-related potentials in impulsively aggressive juveniles: A retrospective chart-review study☆

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1. Introduction

The assessment, treatment and management of aggressive youth represent a major clinical challenge facing pediatric mental health professionals today. Although a number of studies have examined physiological differences among aggressive patients vs. controls, the current literature lacks a comprehensive examination of the electroencephalographic activity of impulsively aggressive juveniles. The current study was designed to fill this void in the literature via a retrospective chart review of 80 male and female juveniles undergoing inpatient treatment for pathologically impulsive aggression. Clinical reports for mid- and late-latency event-related potentials (ERPs) were examined to determine their correlations with aggression characteristics, as well as any differential predictive utility of hemispheric differences and auditory vs. visual potentials. Results indicated that decrements of mid-latency potentials and ERPs evoked by auditory stimuli (vs. late-latency components and visual ERPs) were more highly predictive of aggressive behavior. No significant hemispheric differences were noted. Taken together, these results have theoretical significance for the etiology of impulsive aggression, and perhaps also clinical relevance for the treatment of this condition.

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definitively whether or not the neuroelectric deficits associated with impulse aggression in this population are most accurately reflected via early or late components of the ERP. Further, it is unclear whether or not hemispheric differences in electrical activity may be characteristic in this population, or whether auditory or visual ERPs may be most revealing. The current study was the first of its kind to address these issues via retrospective chart review in a population of 80 male and female juveniles undergoing inpatient treatment for pathological levels of impulse aggression. Based on previous work, the authors hypothesized that, compared to late ERP components, early ERP components would be more highly correlated with impulsive aggression. Given the sparse literature on this topic, differential correlations of auditory vs. visual components and left hemisphere vs. right hemisphere activity with impulsive aggression, were examined as empirical questions.

2. Methods

2.1. Participants

Data were extracted from the medical records of 80 juvenile patients admitted to a residential treatment center in Central Texas for the treatment of pathological impulsive aggression. For admission, the patient were required to have had at least three discrete episodes of failure to resist aggressive impulses, resulting in assaultive acts causing serious physical harm to others (i.e., with bruising, bleeding, or broken bones). Additionally, the degree of aggression expressed during the episodes was grossly out of proportion to any precipitating psychosocial provocation. All patients demonstrated prior psychometric evidence of an intellect (e.g., IQ) of 70 or above. Excluded from admission were individuals who used a non-native language or who did not speak English, were deaf, blind, or had severe mobility problems, suffered with severe medical illness (e.g., AIDS), were pregnant, had a history of arson, or had other conditions that could be a safety concern or would prevent them from participating in individual, group, and family psychotherapy.

Blair, 2008) to the most recent theories regarding an overactive hypothalamic-pituitary-adrenal axis response (van Goozen and Fairchild, 2008; Lopez-Duran et al., 2009) and various genetic factors (Craig and Halton, 2009). Certainly, a combination of these factors might lead to the development of aggressive behaviors in childhood, as well as the potential for persistence of these behaviors into adulthood. In fact, studies have shown that these types of issues tend to exist not only in impulsively aggressive children, but also in impulsively aggressive adults (Hawes et al., 2009).

In clinical practice, the electroencephalogram, (EEG) is frequently used to evaluate juvenile patients with impulsive aggression. Historically, increased inter-ical irritability and impulsive aggression have been noted among individuals with temporal-limbic epilepsy (Spies et al., 1985). Also consistent with a neurobiological focus, a large number of studies have shown a relationship between EEG abnormalities and impulsive aggression (Stein et al., 1995). Enhanced cortical slow wave activity, particularly in the delta frequency range, (e.g., less than 4 Hz) is one relatively consistent finding that has been successfully replicated (Volavka, 1990; Houston and Stanford, 2005; Patrick, 2008). In addition, slow wave EEG activity in adolescence has been shown to predict the emergence of antisocial behavior later in life (Rainie et al., 1990; Patrick, 2008). The aforementioned authors have interpreted these findings as evidence of cortical immaturity resulting in impaired inhibitory control, and cortical underarousal that predisposes towards compensatory stimulation seeking (See Patrick, 2008 for review).

More recently, the examination of event related potentials (ERPs) in aggressive, juvenile populations has become more prevalent (Pogarell et al., 2007). Like the EEG, the ERP can measure abnormal brain activity associated with impulsive aggression; however, the ERP differs from traditional EEG measures, in that it is thought to reflect the brain’s time-locked, electrical response to a specific stimulus. According to Connor (2002), the first 100 ms of ERP signal may correspond with very basic brainstem activity; whereas, the next 200 to 300 ms of ERP signal may correspond to limbic processing, and the next stage of 300–500 ms following stimulus presentation may correspond to cortical perceptual and cognitive processing. Using the negative components as an example, the N100 (e.g., negative peak 100 ms following stimulus presentation) reflects processing of simple sensory parameters of the stimulus (intensity, duration, complexity), while the N200 may reflect response inhibition (the opposite of impulsivity), and the N400 reflects higher level linguistic and semantic processing.

Decrements of the amplitude and latency of these characteristic waveforms have been noted among populations with impulsive aggression (vs. controls), most frequently in the P300 ERP, which occurs approximately 300–900 ms following the presentation of a rare, target stimulus (Birch et al., 1988; Barratt et al., 1997; Gerstle et al., 1998; Mathias and Stanford, 1999; Patrick, 2008). Similarly, such findings have also been noted among individuals with antisocial personality disorder, specifically with regard to abnormal maturation of the pre-frontal cortical generators of the P300 waveform (Bauer et al., 1994; Bauer and Hesselbrock, 1999, 2001, 2003; Patrick, 2008). Patrick (2008) suggests that this dispositional vulnerability to impulse control problems, reflected in the specific ERP decrements described above, may be the key to understanding impulsive aggression. Such findings are supported by our own recent studies of impulsively aggressive juvenile populations, in which long latency ERPs (e.g., 500 ms following stimulus presentation) were found to be more sensitive than traditional EEG measures to the neuroelectric characteristics of impulsive aggression (Fisher et al., 2008).

The literature regarding examination of earlier components of the ERP (e.g., P100, N100, and P200) among impulsive aggressors vs. controls is sparse. One study, by Houston and Stanford (2001) examined psychophysiological differences in arousability among adults displaying impulsive aggressive outbursts. Photic stimulation was used to evoke P100, N100 and P200 waveforms, components occurring 100 and 200 ms following stimulus presentation, respec-

2.2. Demographic characteristics

Participants ranged in age from 6 to 17 years, with a mean age of 13 years. The participants were predominantly male (56 males and 24 females) and were predominately right hand dominant (74 right handed, 6 left handed). With few exceptions, the
participants were Caucasian, and self-reported their state of residence as either Texas or California. Fifty percent of participants had completed 7th grade or higher.

2.3. Electrophysiological procedure

Participants were seated in a comfortable chair in an electrically shielded room located in a quiet section of the residential treatment facility. The EEG was conducted by a trained EEG technician employed by the residential treatment facility, under the supervision of a licensed, board certified, neurologist with specialty training as an electroencephalographer. The technician explained the procedure to the participant. The participant’s head was measured and marked according to the International 10/20 System of Electrode Placement and 6 mm, Grass Gold EEG electrodes applied using standard technique (e.g., collodion, Grass paste/ tape or electrode cap). The instrument was calibrated for a 50 µV/signal (60 cycle filters off), 5 µV/mm sensitivity, high linear frequency filter of 70 Hz, and low frequency filter at 1.0 Hz, and the electrodes were checked for proper impedance (more than 0.5 k-Ohm and less than or equal to 5 k-Ohms). All ERP procedures were conducted in accordance with recommendations of Cognitrace, the manufacturers of the EEG machine used by the facility (see Duffy et al., 1979). It is important to note that some aspects of Cognitrace methodology are proprietary in nature and cannot be included in the current manuscript. The authors realize that this reduces the ability of other researchers to replicate the findings of the current study; such issues are a caveat of retrospective chart review studies.

Auditory and visual ERPs were routinely conducted on juveniles admitted for psychiatrically impairing aggression. The ERPs were long latency (500 ms) electrical responses time-locked to auditory (bilateral 86 dB SPL, 1000 Hz tone, rise and fall time 10 ms) or visual (Grass strobe light flash, 18 in from closed eyes) stimuli, averaged from the background EEG over 100 trials for each type of stimulus. All stimuli were presented in random format with at least 1000 ms intervals. Auditory and visual ERPs were collected in separate blocks. The test results were interpreted by a board certified pediatric neurologist with specialty training as an electroencephalographer. The neurologist was blind to the participants’ diagnoses (e.g., only participants’ age and gender were given). The auditory and visual ERPs consisted of averaged records taken from periods of artifact-free EEG. Data were baseline corrected and eye movement artifacts were corrected using proprietary software from Cognitrace (e.g., manufacturers of the EEG machine; see Duffy et al., 1979). For each of the 19 electrodes (Fp1, F3, F7, Fp2, F4, F8, Fz, C3, C4, T3, T4, P3, P4, T5, T6, O1, and O2), the raw waveforms available to the neurologist consisted of a graph of the averaged ERPs, time locked from the moment of stimulation, with data points taken every 20 ms for a total of 500 ms. For each auditory and visual ERP, the neurologist had access to individual ERP graphs as well as to averaged graphs, which were computerized and compared to age- and gender-matched, proprietary norms provided by Cognitrace (e.g., manufacturers of the EEG machine). The operational definition of abnormal referred to a condition in which participants’ ERP wave amplitudes differed from the norm amplitude by at least 2.5 S.D. In this way, the amplitude or latency of the waveforms (auditory and visual) was considered normal or abnormal at each peak. However, if the amplitude of any peak did not reach 5 µV in negative or positive amplitude, the ERP was considered absent and abnormal. Also, in terms of latency at each peak, the ERP was considered abnormal if the latency was early or late by 50 ms or more.

Using the standards described above, for both auditory and visual paradigms, ERPs were categorized as either “abnormal” or “normal” by the facility’s pediatric neurologist. The activity of all available electrodes was taken into consideration during this categorization. Information regarding how many abnormalities were due to amplitude and/or latency differences in particular was not available, nor was the actual amplitude and latency values. The criterion of 5 µV for abnormal ERPs was determined by the aforementioned pediatric neurologist. Due to the dichotomous nature of the neurologist’s coding for the normality (or abnormality) of the ERPs, the percentage of patients who were deemed “abnormal” due to the 5 µV criteria is not known.

3. Results

3.1. Electrophysiology

In order to determine the “abnormal” or “normal” designation for each patient’s ERP, the facility’s pediatric neurologist examined the activity of all 20 electrodes. A designation of “abnormal” ERP refers to an either/or situation in which the patient exhibited either abnormal amplitude, or abnormal latency, or the combination of both abnormal amplitude and latency. As noted previously, amplitude and latency information was not available for analysis; thus, the following results apply only to the dichotomous categorization available in the neurologist’s report for each patient. Separate diagnostics were conducted for left hemisphere vs. right hemisphere, early ERPs vs. late ERPs, and auditory ERPs vs. visual ERPs.

Analysis of electrophysiological data indicated a tendency for larger proportion of ERP abnormalities in the left hemisphere compared to the right but these differences were not statistically significant. Significant findings were observed in the auditory (AERP) versus visual (VERP) comparisons and in the early component (100–300 ms) versus late component (300–500 ms) comparisons, using McNemar’s test for correlated proportions. For auditory versus visual comparisons, McNemar’s test for the difference was significant (p<0.01, two tailed), showing a greater proportion of ERP abnormalities in the auditory ERP. For the early versus the late component comparisons, McNemar’s test for the difference was also significant (p<0.01, two tailed), showing a greater proportion of ERP abnormalities for the early component ERPs. Results are shown in Table 2.

4. Discussion

The current study was designed to fill a void in the literature regarding the neuroelectric characteristics of impulsively aggressive juveniles. The study hypothesis that shorter-latency ERPs (100–300 ms) would show more abnormalities than long-latency ERPs (300–500 ms) was confirmed by a small, but statistically significant
4.1. Limitations

There are limitations in this study inherent in any retrospective endeavor, such as lack of control variables, lack of availability of records, and the quality and completeness of available data. For instance, although information regarding the patients’ medications would certainly have enhanced the manuscript, this information was not reliably available for the ‘snapshot’ period in which the electrophysiological procedures were performed. Certainly, this is one of the caveats of a retrospective chart-review study in which information was originally documented for clinical, rather than research, purposes. Future studies, utilizing a prospective research design could address this issue more thoroughly. Also, as there was no random assignment to the intake of the residential treatment facility from which participants were derived, any circumstances (e.g., managed care, low socio-economic status) which might have precluded patients from being admitted to the treatment facility could have also impacted the ecological validity of the results.

Additionally, the neurologist’s dichotomous coding scheme for the “early” components of the ERP (P100, P200, N100 and N200) versus the single “late” component of the ERP (P300) prohibited the analysis of any individual waveforms. Because the cognitive correlates of the P1, N1, P2 and N2 may differ, individual analysis of these ERPs could provide additional information on the electrophysiological correlates of impulsive aggression. Similarly, as the amplitude and latency data for individual ERPs were not available for study, the neurologists’ reports in the medical record were the only basis for gauging the normality (e.g., normal vs. abnormal) of the visual and auditory ERPs. Future studies, including a more in-depth analysis of the amplitudes and latencies of individual ERPs may provide additional insight into juveniles with impulsive aggression.

In addition, future studies examining the potential correlations between ERP findings and neuropsychological assessments of memory could help to clarify the nature of neural dysfunction in this population. To partially address this issue, post-hoc analyses were conducted on the current dataset using neuropsychological data from patients’ intake assessment. Summary variables of absolute memory differences (e.g., verbal minus visual memory from the Wide Range Assessment of Memory and Learning, Version 2; Sheslow and Adams, 2003) and a summary variable of visual+auditory ERP data (“any ERP abnormality”) were found to be significantly positively correlated. Although this correlation supports the notion of limbic dysfunction among impulsive aggressors, further study of this population, measuring a broader range of cognitive functions and using a complete psychometric battery is warranted.

Given the high degree of co-morbidity in the present patient sample (See Table 1) and the ERP abnormalities associated with some of these diagnoses (for instance, Attention Deficit Hyperactivity Disorder), it is possible that some of the ERP findings of the current study might not be specifically related to impulsive aggression per se. Future studies should more closely examine overlapping diagnoses and their contributions to both impulsive aggressive behaviors, and variations in neural function. Further, the range of ages included in this study was fairly broad. As mentioned previously, brain maturation differences could greatly affect ERPs over this particular age range. In addition, males and females may mature at different rates (Raznahan et al., 2010). However, in the current study, when post-hoc analyses were conducted on data coded for yes/no as to the presence of “any ERP abnormality”, males and females didn’t differ statistically with regard to their distribution in these categories. Although a longitudinal assessment was beyond the scope of the current study, future work should consider how aging might affect the potential neural substrates of impulsive aggression.

4.2. Conclusion

Impulsive aggression is a complex and multifaceted behavior with both biological and psychological influences. With regard to biological
etiology, theories have focused on neuroelectric abnormalities. The current study provides a comprehensive assessment of ERP characteristics of a large group of male and female inpatients undergoing treatment for pathological impulsive aggression. Results suggest that auditory ERPs in the range of 100 to 300 ms after stimulus presentation are most frequently associated with impulsive aggression. These findings lend support to the notion that impulsive aggression may be related to the phenomenon of ‘limbic kindling’ (Kraus, 2000) and may have implications for improved clinical treatment of this condition.

References


