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The role of anterior cingulate cortex and amygdala on criminal behavior

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Abstract: : Study of brain malfunctioning effects on the behavior of criminal were carried since 18th century. Two types of brain regions emphasized in the review are Anterior Cingulate Cortex (ACC) and Amygdala. ACC functions as recognizing faults or deficits within certain standards, making expectations and predictions before carry out a task and regulating emotions, while amygdala function in emotion processing such as fear, anger and happiness. The synthesis looked into the role effect of ACC and amygdala towards the behavior of criminals in terms of antisocial and aggressiveness. Quantities article from 2007-2014 related the research were synthesized to look at the effects of the research. Right Amygdala was found to have higher effects compared to the rostral ACC compared to other brain regions. In summary, different regions of ACC and amygdala had indicated different level of effects towards the behavior of a criminal as discussed in the synthesis.

Key words: Anterior cingulate cortex; ACC; Amygdala; Antisocial behavior; Aggressive behavior

1. Introduction

This paper reports on synthesis of studies related to the effect of Anterior Cingulate cortex and amygdala on criminal behavior. Articles were located using computer search from websites and online database such as Centre of Academic Information Services (CAIS) online database, Google scholar and Journal Storage (JSTOR), SAGE journals, Research Gate, Science Direct, National Center for Biotechnology Information (NCBI) and Academia.edu. Journals articles searched are specifying title of Anterior Cingulate Cortex, Amygdala, Criminals antisocial and aggression behavior around the year of 2007 to 2014. About record of 20 abstracts and articles are produced.

There are seven criteria for selection of study. The first criteria are the journal articles selected are related to ACC, amygdala and individual with psychopath or criminal behavior since this study is about the effects of ACC and amygdala on the behavior of a criminal. Keywords such as ACC, amygdala, antisocial behavior, psychopath, and aggression behavior are used for literature search. For second criteria, the research design used for journal articles selected is restricted for only experimental research, and must able to bring intervention towards the sample used, in the case is individual with criminal behavior (Fauzan, 2006). Third, selected journal articles have to be quantitative in nature, (Fauzan, 2006). Fourth, the effect outcome has reading measure (Fauzan, 2006). Fifth, selected journal articles includes journal articles from year 2007 to 2014 which will narrow down the studies published in current year with consistency on technology used (Fauzan, 2006).

2. Individuals with antisocial behavior

In most research, antisocial behavior was defined as parasitic lifestyle, poor control on behavior, detached, predatory style as a strategy to meet their instant needs without considering other consequences, which is classified under psychopathic personalities (Yang et al., 2009). It was believed that antisocial behavior of an individual play a major role in crime involvement, which then used to measure and predicts one's in the future crime risk. Individuals which exhibit with antisocial characteristics, from the range of childhood to male adult, especially those who already involve in crime, were recruited for study of their brain areas, which in this study that focus on anterior cingulate cortex (ACC) and amygdala. Participants were provided with a written consent form approved by University of New Mexico for the research on ACC conducted by Dr. Kent Kiehl and University of Southern California institutional review board in the research on amygdala conducted by Dr. Adrian Raine.

3. Individuals with aggressive behavior

Aggressive behavior on the other hand, was contributed by the variation in emotional processes (Boes et al., 2008). Human aggression is an omnipresent phenomenon with important social consequences, where the neurobiology of impulsive aggression is gradually understood although the sources behind are clearly multifactorial (Ducharme

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et al., 2011). Impulsive aggression can be defines as lower threshold for activation of motor aggressive responses to external stimuli without sufficient reflection or regard for the behavior aversive consequences (Siever, 2008).

Healthy children with aggressive behavior were studied instead of those with mental disorders which require medication treatment to study the role of ACC towards aggressive behavior, where the findings was then implemented with pathological disorder and antisocial behavior. Study on amygdala towards aggressive behavior on the other hand, has its sample recruited from psychopathic individuals. All samples were provided with written consent form which is approved by University of Iowa Human Subjects Institutional Review Board in the research on ACC conducted by Dr. Aaron D. Boes, and University of Pittsburgh Institutional Review Board in the research on amygdala conducted by Dr. Dustin A. Pardini.

4. Instruments and checklists

4.1. (GNG) go/no-go task

(GNG) go/no-go task is a general method where participants are required to restrain a prepotent motor reaction was used to measure behavioral impulsivity during fMRI (Aharoni et al., 2013). The task presents participants with letter "X", a frequent occurring goal with occurrence probability of 0.84, interleaved with the letter "K" which functions as a less-frequent distractor with occurrence probability of 0.16 on computer screen (Aharoni et al., 2013). Participants were required to depress a button with their right index finger as fast and precisely as possible whenever they saw the target ("go" stimulus) and not the moment they saw the distracter ("no-go" stimulus), and because the occurrence of target is more frequent compared to distracters in this task, a proponent reaction toward the targets is obtained (Aharoni et al., 2013). A presented distractor requires participant to restrain their response on button which will increase the rate of commission errors (Aharoni et al., 2013). Commission error rate was characterized as the quantity of examined commission errors among total no-go trials (Aharoni et al., 2013). The ability to observe error-related conflicts and selectively restrain the proponent go response on cue was considered as successful performance in this task (Aharoni et al., 2013). Participants completed around 10 trials of short training session before scanning (Aharoni et al., 2013).

4.2. Pediatric behavior scale (PBS)

The Pediatric Behavior scale (PBS) is a tool used to screen emotions and behavioral problems obtained from Child Behavior Checklist (CBCL) (Achenbach & Edelbrock, 1983) and Pediatric Behavior Scale (Lindgren & Koeppl, 1987). A parent and a teacher were asked to rate a subject by using 4 point Likert scale (0-3), where lower score specify less problems (Boes et al., 2008).

In previous research, the conduct scale provided the behaviors of interest to evaluate symptoms of aggression and defiance (Boes et al., 2008). Questions regarding the individuals were: 1) mean or cruel to others, 2) bullies, threatens or picks on other children, 3) initiate fights, 4) punch, bite, or flings things at people, 5) rebellious, against rules, 6) argues or quarrel, 7) bad-tempered; gets annoyed easily, 8) loses temper; has temper outbursts, and 9) shouts or screams a lot (Boes et al., 2008). Impulse control scale was as well included due to high co-occurrence of conduct problems with signs of impulsivity and hyperactivity a second PBS scales (Boes et al., 2008). The scale evaluated the behaviors as in: 1) impulsive; acts without stopping to think, 2) want things right away without the ability to wait, 3) disrupts, blurts things out, or talks out of turn, 4) fails to complete things he or she starts, 5) hyperactive; 6) squirms or restless, and 7) restless (Boes et al., 2008).

This scale was used as a covariate in statistical analyses to make sure that individual differences in impulsiveness and hyperactivity did not confuse structure-function results in regards with aggression-defiance (Boes et al., 2008). The collected PBS scores from the parent and teacher were later summed as a means of data reduction (Boes et al., 2008).

4.3. Hare psychopathy checklist-revised (PCL-R).

Psychopathy Checklist-Revised is an analytical instrument used to rate an individual's tendency towards psychopathic or antisocial behavior (Haycock, 2014). It is originally designed to evaluate accused people or those who conducted crimes (Haycock, 2014). PCL_R included a 20-item symptom rating scale that permits qualified surveyors to evaluate the level of psychopathy in an individual with archetypal psychopath, which is accepted by numerous fields as the best technique to decide the existence and degree of psychopathy in an individual (Haycock, 2014).

PCL-R offers a total score that signify how intimately the assessed individuals corresponds the "perfect" score of a rate of a typical psychopath (Haycock, 2014). Every 20 items is given score of 0, 1, or 2 depends on how perfectly it relates to the analyzed individuals. Typical psychopath would obtain a maximum score of 40, where individuals with no psychopathic traits will obtain score of 0. Individual that score 30 or above will be identified as psychopathy, where people without criminal background scored around 5 (Haycock, 2014). On the other hand, non-psychopathic criminal will score around 22 (Haycock, 2014).

4.4. Instrument for assessment

MRI scanning: Magnetic resonance imaging (MRI) is a machine that used for brain structure imaging, which function to view the anatomical structure of the brain and discover unobserved anatomical abnormalities caused by disease or traumatic event (Golden, 2011).

In the study of ACC conducted by Boes et al., MRI scans were acquired by using 1.5 Tesla General Electric SIGNA System (GE Medical Systems, Milwaukee, WI), where the three-dimensional (3D) T1 weighted images were obtained in the coronal plane using a spoiled grass sequence with several parameters such as: 1.5 mm coronal slices, 40˚ flip angle, 24 msec repetition time (TR), 5 ms echo time (TE), 2 number of excitations (NEX), 26cm field of view (FOV) and a 256X192 matrix (Boes et al., 2008).

In the study of amygdala conducted by Yang et al., structural magnetic resonance images were collected on a 1.5-T Phillips (Shelton, Connecticut) S15/ACS scanner with 34 milliseconds of repetition time, 12.4 milliseconds of echo time, and 0.9x0.9x1.7mm of voxel size (Yang et al., 2009). Before the process of delineation, each image volume was priority corrected for magnetic field inhomogeneities, head tilt and arrangement by using 6-parameter rigid-body registrations (Yang et al., 2009). Throughout registration method, the volumes of the image were localized in a common coordinate space (Yang et al., 2009). To improve the visibility of anatomical aspects in recognizing the structure for the region of interest (ROI), which is amygdala, images were first resampled to 1-mm thickness (Yang et al., 2009).

fMRI scanning: Functional magnetic resonance imaging (fMRI) is a technique used for brain activity measurement, a modification of MRI (Delvin, 2013). It function by identifying the alteration in blood oxygenation and flow occurrence in response with neural activity, as a part of brain region is more active compared with other brain region, it consumes more oxygen and thus cause an increase of blood flow to that specific region to fulfill the oxygen demands (Delvin, 2013). Activation maps can be produced through fMRI to present which region of the brain is involved in specific mental process (Delvin, 2013).In the study of ACC conducted by Aharoni et al., activation of ACC is measured by using fMRI. Current fMRI study included a priori ROI testing which use every imaging data comprised in a dataset known as Dataset S1 for each subject in the form of β-value. Codes and scores from other predictors and reported measures were also included in Dataset S1.

Two scanning were run with a composed 246 visual stimuli, and was shown to participants using a computer-controlled visual and auditory software (Neurobehavioral Systems) called Presentation (Aharoni et al., 2013). A rear-projection screen mounted at the back opening to the magnet bore subtended an angle of visual with ~3 x 3.5˚ which display stimulus every 250 ms for participants to view by way of a mirror system joined to the head coil (Aharoni et al., 2013).

5. Synthesis on previous studies

5.1. Research on anterior cingulate cortex (ACC}

Location of rostral region of anterior cingulate cortex:

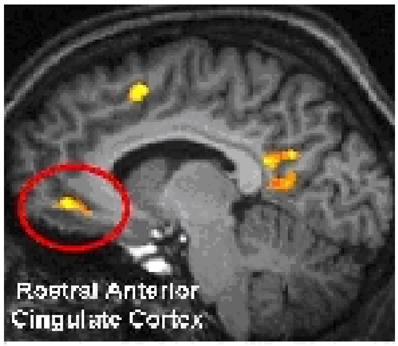

Fig. 1: Location of rostral anterior cingulate cortex
Adapted from depression's flip side shares its circuitry, 2007, retrieved from: http://www.nimh.nih.gov/news/science-news/2007/depressions-flip-side-shares-its-circuitry.shtml.
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According to Aharoni et al. (2013), parts of the brain that relate the control of impulse have been well defined. Anterior cingulate cortex (ACC) is one of the limbic regions often connected with processing of error, monitoring conflict, selection on response and learning avoidance (Holroyd & Coles, 2002). Research on animal lesions had indicated that the central impairment to the anterior cingulate cortex will cause learning problem in behavior regulation (Gabriel et al., 1989). Cingulate damage in humans on the other hand, presented result of alteration in disinhibition, indifference and violence (Aharoni et al., 2013). Individuals with anterior cingulated cortex epilepsy usually exhibit psychopathic or sociopathic behaviors (Devinsky et al., 1995). In this reason, patients with injured ACC been categorized as "acquired psychopathic personality" genre (Aharoni et al., 2013)

5.2. Research on orientation of ACC towards antisocial behavior of criminals.

Kent A. Kiehl, a neuroscientist who owns a laboratory in Albuquerque, New Mexico conducted a longitudinal research around 2007 to find out the effect of dysfunctional anterior cingulate cortex (ACC) on prisoners antisocial behavior that would leads to future crime. First, hypothesis regarding activity of ACC connected with a go/no-go (GNG) impulse control task that leads to the prediction of future antisocial behavior was evaluated (Aharoni et al., 2013). Later, the hypothesis was used to conduct in the longitudinal, approaching study towards released criminal lawbreakers (Aharoni et al., 2013).

96 adult male offenders who age ranged from 20 to 52 years (Mean, 33.1; SD, 7.78) were participated

in this study (Aharoni et al., 2013). Before the participants are discharged from correctional facilities, they completed a number of psychological and behavioral assessment measures which is go/no-go (GNG) task and an fMRI-based inhibition task using the Mind Research Network's Mobile MRI system (Aharoni et al., 2013). It was ensured that these participants free of traumatic brain damage and mental illness, with common IQ larger than 70 (Aharoni et al., 2013). After the participants were discharged, they were tracked from 2007 to 2010, with 34.5 mo averaged follow-up period (Aharoni et al., 2013).

An independent sample of non-offender was gathered. Functional imaging results were provided from 102 healthy adult non-offenders (49 men) who age ranged from 23 to 52 year (Mean, 33.92; SD, 9.64) to define the priori peak voxel, where this sample was drawn from the Olin Neuropsychiatry Research Center at the Institute of Living Hartford Hospital and the surrounding society of Hartford, CT (Aharoni et al., 2013).

Connection between ACC reaction and the percentage of charged errors in the GNG task was examined by using hierarchical linear regression (Aharoni et al., 2013). It was found that lower ACC activity entered at step 2 connected to a higher degree of commission errors, managing for variance attributable to age at step 1 (R^2=0.08, ΔR^2=0.04, β=-0.21, P<0.05), where mean commission error and hit rates on GNG task were 25.04 (13.00) and 96.56 (6.40) respectively (Aharoni et al., 2013).

A Kaplan-Meier survival function was calculated to illustrate the proportion of participants present any crime rearrest over the 4-year follow-up period, discriminate other particular risk consequences which presented in figure 2 (Aharoni et al., 2013).

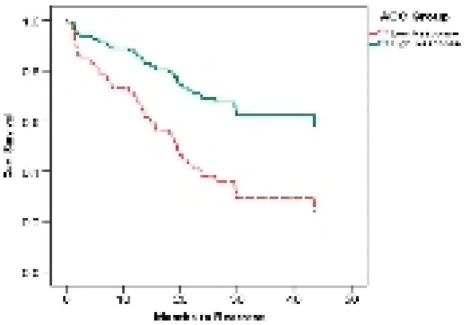

Fig. 2: Cox survival function presented proportional rearrests survival rates of high with sold green indication vs. low with dashed red indication among ACC response groups for any crime over a 4-year period.

The results of this median split analysis were corresponding to the parametric model: bootstrapped B=0.96; SE=0.40; P<0.01; 95% CI, 0.29-1.84. Among ACC activity group, low mean survival times to rearrests indicated 25.27 (2.80) mo with overall probabilities of 60% while the high mean survival times to rearrests indicated 32.42 (2.73) mo with overall probabilities of 46%. Adapted from " Neuroprediction of Future Rearrests," by E. Aharoni et al., 2013, Proceedings of the National Academy of Sciences of the United States of America, 110(15), p. 6223-6228, Copyright 2015 by the National Academy of Sciences.

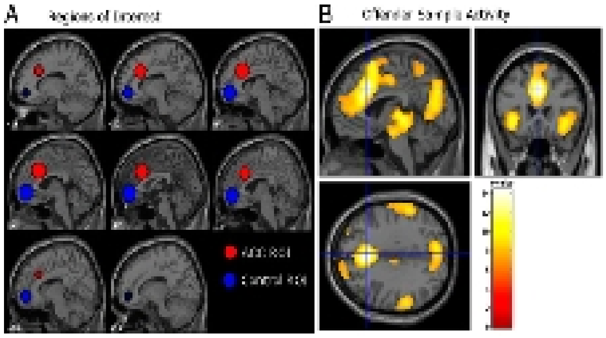

Fig. 3: The priori seed region indicated with red for BOLD

Image a shown the priori seed region indicated with red for BOLD response to commission error vs. accurate hits in anterior cingulate from a GNG task with 102 healthy adult non-offenders independent sample; peak voxel x=-3, y=24, z=33; radius=14mm sphere; t(94)=13.38, P<0.0001, FWE, while priori control region indicated with blue symbolize anterior portion of the medial prefrontal cortex; peak voxel x=0, y=51, z=-6; radius=14mm sphere. For image B, it shown the alteration of mean hemodynamic response in offender sample (n=96) during commission errors vs. accurate hits from sagittal (Upper left), coronal (Right), and axial (Lower Left) orientations. Peak activation situated at x=3, y=24, z=3 within the ACC ROI (P<0.00001, FWE). Adapted from " Neuroprediction of Future Rearrest," by E. Aharoni et al., 2013, Proceedings of the National Academy of Sciences of the United States of America, 110(15), p. 6223-6228, Copyright 2015 by the National Academy of Sciences (Adapted with permission).

5.3. Research on orientation of ACC towards aggressive behavior of criminals.

Another research on study the correlation of the right anterior cingulate cortex volume towards aggression and defiance in boys was conducted by Aaron and his colleagues around 2007 (Boes et al., 2008). The finding in this research was implied to understand neural correlates of antisocial behavior (Boes et al., 2008).

In this research, healthy individual were recruited instead of individual with psychopath. 117 healthy children and teenagers that were 61 boys and 56 girls who age around 7-17 were participated in this study (Boes et al., 2008). To exclude subjects with any medical or neurological disease that require vital medical intervention, a phone screening interview was carried out (Boes et al., 2008). Assessment towards a boy was obtained from a parent and a teacher by using PBS scale (Boes et al., 2008).

The behavioral data revealed low mean levels of conduct problems and impulsiveness or hyperactivity moderately in the sample, which provide a positive skew in the distribution (Boes et al., 2008). It was found that boys had higher levels of behavioral problems relative to girls which then had larger total cortical gray matter volume than girls, although Region of Interest (ROIs) volume had no differences between sexes when expressed as percentage of cortical volume (Boes et al., 2008). For multiple regressions, change in R^2 was statistically significant for step 1 which includes demographic data, total gray matter volume of the cerebral cortex, ratings of impulse control and step 3 that include interaction terms for ROI volumes X sex, with an effect size estimated at 0.29 and 0.10 using Cohen's f^2, is regarded as moderate and small respectively (Boes et al., 2008). There reached a significance for individual variables within step 1 which include SES and ratings of impulse control, and significant interaction effect for sex X right ACC volume and sex X left ACC volume in step 3 (Boes et al., 2008).

For correlation findings, there was a statistically significant negative correlation of conduct ratings and volume of the right ACC in boys [r=-0.42, p=0.002], while girls present a non-significant negative correlation with left ACC [r=-0.22, p=0.12] (Boes et al., 2008). By using ANCOVA, significant differences in right ACC present in comparing boys with High versus Low conduct problem score is tested, and found that boys with higher score had significantly less right ACC volume [F = 14.21, p=0.001]. The size of the effect was large, with an estimate at 0.289 using partial Eta squared (Boes et al., 2008).

The results provide initial support that the right ACC as neuroanatomical correlate of aggressive and defiant behavior in boys (Boes et al., 2008). Generally, the significant findings were provided as follows: 1) there was a significant interaction of sex and ACC volume mutually in a regression model predicting aggressive and deviant behavior, 2) significant negative correlation of aggression-defiance ratings and right ACC volume in boys is revealed by using Spearman's partial correlation (r=-.42), and 3) boys with high levels of aggression-defiance had significantly less volume of the right ACC when compared with subjects of low levels of aggression-defiance (r=-.42). For girls, left ACC correlated negatively with aggression-defiance, but result was not statistically significant (Boes et al., 2008).

Results of neuroanatomical correlate of aggression-defiance in ACC indicates the possibility that anatomical variation in this cortical area may reveal functional variations clearly for differences in behavioral, which is supported by traditional techniques revealing ACC function in social behavior and aggression (Boes et al., 2008).

Table 1 indicated the samples of boys and girls with similar outcomes on demographic measures.

Table 1: The demographic, behavioral, and structural information between boys and girls

Variable	Measure	Boys (n = 61)	Girls (n = 56)	Sig. (p)
Age	**Range**	7.75 – 17.92	7.08 – 17.58	
	Mean (s.d.)	12.08 (2.71)	12.49 (2.87)	.42
IQ	Mean (s.d.)	112 (16)	108 (13)	.11
SES	Mean (s.d.)	2.29 (.57)	2.28 (.52)	.94
Handedness		58 RH, 2 LH, 1 A	50 RH, 6 LH	
Impulsivity Rating	**Range**	0 – 27	0 – 23	
	Mean (s.d.)	6.32 (5.39)	3.94 (4.78)	.01
Conduct Rating	Range	0 – 24	0 – 16	
	Mean (s.d.)	5.81 (5.28)	1.66 (3.16)	.01
Total Cortex Volume (cc)	Mean (s.d.)	504 (35)	455 (29)	.000
R ACC*	Mean (s.d.)	.78 (.11)	.81 (.14)	.23
L ACC*	Mean (s.d.)	.78 (.12)	.81 (.14)	.23
R vmPFC*	Mean (s.d.)	2.93 (.21)	2.96 (.25)	.74
L vmPFC*	Mean (s.d.)	3.03 (.24)	3.01 (.23)	.66

Sig. = Significance, independent samples t-test.

*Regional structural measures are expressed as a percentage of total cortex volume.

ACC = anterior cingulate cortex, A = ambidextrous, L = left, LH = left handed, R = right, RH = right handed, SES = parent socio-economic status, vmPFC = ventromedial prefrontal cortex, Vol = volume

Note: From "Right anterior cingulate cortex volume is a neuroanatomical correlate of aggression and defiance in boys," by Boes et al., 2008, *Behav Neurosci*, 122(3), p. 677-684

5.4. Research on amygdala

Amygdala has been commonly known as a vital element in the neural circuit underlying emotional processing, where it's intact is found necessary for fear conditioning (Yang et al., 2009). Although the function of amygdala nuclei in human remains unclear, a study of the function of amygdala nuclei on rats conducted by Lanuza and his colleagues had provided the evidence of amygdala involvement in emotion processing (Lanuza et al., 2008). Hence, amygdala injury had been hypothesized to be a factor towards poor fear conditioning in individuals with psychopathy (Yang et al., 2009). It also been hypothesized that amygdala disturbances in composition may contribute social dysfunctional and moral decision making among individuals with psychopaths (Yang et al., 2009).

5.5. Research on orientation of amygdala towards antisocial behavior of criminals

Regional structural deformity in the amygdala of psychopath was studied by Yaling Yang and his colleagues. Psychopath is a clinical condition conceptualized by a mixture of core psychopathic characters such as shallow affect, conning and manipulative; and antisocial behavior outcomes such as parasitic lifestyle and poor behavioral control (Yang et al., 2009).

86 subjects from 5 impermanent employment agencies in Los Angeles, California that demonstrate relatively higher rates of psychopathy or antisocial personality were enrolled in this study (Yang et al., 2009). The antisocial personality of the individual was evaluated by using Psychopathy Checklist-Revised (PCL-R) and supported by 5 sources of security data (Yang et al., 2009).

The 5 sources of security data were (1) the Interpersonal Measure of Psychopathy ratings; (2) self-reported crime and aggression evaluated using an adult extension of the National Youth Survey self-report criminal behavior measure; (3) transcripts of criminal history attained from the Department of Justice; (4) data resulted from, and behavioral observations made during, the Structured Clinical Interview for Axis I *DSM-IV* Disorders and Axis II Personality Disorders, and (5) independent Interpersonal Measure of Psychopathy ratings created by 2 different laboratory assistants throughout separate stage of analysis (Yang et al., 2009).

A cutoff of high score of 23 and low score of 15 on the total PCL-R score was used to identify psychopath, which then found a total of 27 subjects with psychopathy where their PCL-R score range around 23-40, and 32 controls with PCL-R score range around 5-14 (Yang et al., 2014). The cutoff was preferred in reason to be constant with previous research on the correlation of specific brain regions towards criminal behavior and identical to the taxometric studies of the PCL-R suggestion with the optimal cutoff (Yang et al., 2014). In this study, term of individuals with psychopathy refers to community individuals with a PCL_R score higher than 23.

To identify the structure, images were first resampled to 1-mm thickness to enhance the anatomical elements visibility (Yang et al., 2009). A tracing for amygdala in coronal brain slices from posterior to anterior when using the digitized surface contours concurrently displayed in both sagittal and transverse planes to assist a more precise identification of the boundaries that split amygdala from surrounding structures (Yang et al., 2009). The image was shown as below.

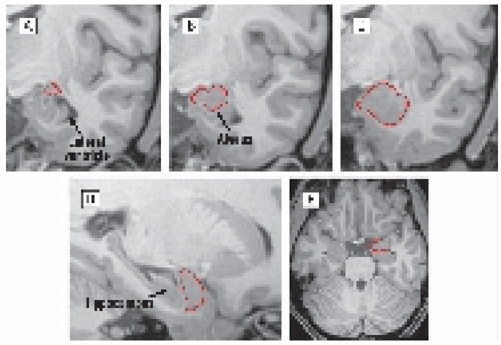

Fig. 4: Amygdala was traced in high-resolution T1-weighted images by using the software MultiTracer.

The image of A-C showing tracing performed in contiguous coronal slices from posterior to anterior while referred to image D that present the orthogonal sagittal and image E that present transverse planes for the purpose of verifying the accurate anatomical boundaries identification. Although only right amygdala tracing are demonstrated, same protocol was used to trace left amygdala. Adapted from "Localization of Deformations within the Amygdala in Individuals with Psychopathy," by Y. Yang et al., 2009, *Arch Gen Psychiatry*, 66(9), p. 986-994 (Copyright 2009 by the National Center for Biotechnology Information) (Adapted with permission).

Individuals with psychopathy presented a vital decrease in the volume of amygdala compared with controls ($F_{2,\ 55}$=3.85; P=.03), with whole-brain volume as covariate (Yang et al., 2009). They showed a 17.14% decrease in left amygdala volume and 18.93% decrease in right amygdala volume when compared with controls (Yang et al., 2009). On the other hand, surface-based modeling analysis indicated that there is a difference in the bilateral shape of the amygdala which consistent with volumetric findings (left, permutation-corrected P=.047; right, P=.002) (Yang et al., 2009). Results remained significant after whole-brain volume, socioeconomic status, and substance/alcohol dependence are controlled (left, permutation-corrected P=.049; right, p=.006) (Yang et al., 2009).

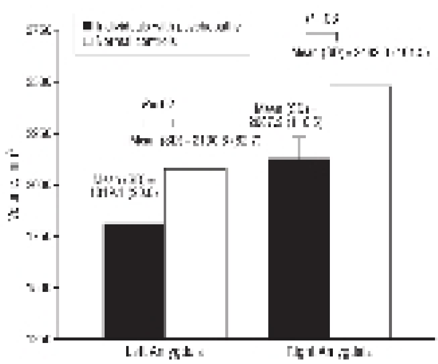

Fig. 5: Amygdala volumes of psychopathy individuals and normal controls, together with total brain volumes as covariate

The standard error was represented as vertical lines, and the group means (SD) volume is indicated. Adapted from "Localization of Deformations within the Amygdala in Individuals with Psychopathy," by Y. Yang et al., 2009, *Arch Gen Psychiatry*, 66(9), p. 986-994 (Copyright 2009 by the National Center for Biotechnology Information)(Adapted with permission).

5.6. Research on orientation of amygdala towards aggressive behavior of criminals.

Another longitudinal study conducted by Dustin A. Pardini and his colleagues had been carried out around 1986 to examine the possibilities of male subjects with lower volume of amygdala have past history of psychopathic characteristics during early childhood and higher risk of involvement in future aggression (Pardini et al., 2014).

503 boys from first-grader were initially recruited from youngest cohort of the Pittsburgh Youth Study (PYS) who attend Pittsburgh public schools in 1986-1987 after an early screening assessment that measures antisocial behaviors of boys obtained from parents, teachers, and self-report instruments (Pardini et al., 2014). First assessment took place when boys averaged 7.46 years of age with standard deviation of 0.55, and the assessment conducted every 6 months for 4 years, with annual assessments take place for the next 9 years (Pardini et al., 2014). Two extra assessments were carried out when the men averaged 25.78 with standard deviation of 0.96 and 29.25 with standard deviation of 1.11 years of age (Pardini et al., 2014).

At the age of 26, a subsample of 20 men from the PYS with records of chronic serious violence (CSV), 16 men with transient serious violence (TSV) and 20 men with records of no serious violence (NSV) were recruited for neuroimaging substudy (Pardini et al., 2014). These men were later compared by using analysis of variance in terms of left and right amygdala volume (Pardini et al., 2014). Measurement on aggression were categorized into several stages: mean age of Childhood Measures for mean age of 7.5-11 years, Adolescent measures for mean age of 16 years, Assessment Concurrent with Structural Scan for mean age of 26 years, and Postscan Follow-Up for mean age of 29 years (Pardini et al., 2014). Linear regression was then used to investigate the association between amygdala volume and individual differences in aggressive or psychopathic characteristics during time scan with the total sample (Pardini et al., 2014).

For the result obtained from Concurrent with Structural Scan, there is no significant differences in left amygdala volume between NSV (mean = 1597, SD = 295), TSV (mean = 1489, SD = 302), and CSV (mean = 1587, SD = 312) men ($F_{2, 53} = 0.75$, $p = 0.48$) (Pardini et al., 2014). However, dimensional analyses with all participants implied that lower left and right amygdala volume was associated with higher level of ASR aggression and premeditated aggression (Pardini et al., 2014). Left amygdala with lower volume was as well correlated with higher levels of IAR aggression (uncontrolled anger outburst) (Pardini et al., 2014). Amygdala was not significantly correlated to verbal or physical aggression measured with the AQ-SF and overall levels of psychopathic features (Pardini et al., 2014).

For the result obtained from Childhood and Adolescence measurement, it was indicated that lower amygdala volume was significantly correlated with aggression and psychopathic characteristic measurement in childhood and adolescence (Pardini et al., 2014). Left amygdala with lower volume was correlated with higher teacher-reported aggressive behaviors and interpersonal callousness across childhood (Pardini et al., 2014). For adolescence, lower right amygdala volume was connected with higher proactive aggression and overall psychopathic characteristics of an individual (Pardini et al., 2014).

It was found that men with lower amygdala volume had display higher levels of aggressive behavior and psychopathic characteristics from childhood to early adulthood (Pardini et al., 2014). The associations between adult amygdala volume, earlier aggressive behavior and psychopathic features are presented in table 2.

Table 2: Associations between adult amygdala volume and earlier aggressive behavior and psychopathic features

	Amygdala Volume							
	Left				Right			
Dependent Variables	B	SE	p	ΔR^2	B	SE	p	ΔR^2
Childhood (Ages 7.5–11)								
Aggressive behavior[a]	−.14	.06	.023	—	−.04	.05	.497	—
Interpersonal callousness[a]	−.15	.06	.015	—	−.08	.05	.192	—
Adolescence (age 16)								
Reactive aggression[a]	−.09	.07	.200	.01	−.08	.07	.236	.01
Proactive aggression[a]	−.14	.10	.176	.03	−.21	.10	.038	.06
Aggressive behavior (YSR)	−.03	.20	.350	.01	−.06	.03	.064	.04
Psychopathic features	.02	.02	.208	.02	.42	.02	.043	.06

All estimates are after controlling for potential confounds with a backward stepwise inclusion procedure. Amygdala volumes were transformed to Z-scores before the analysis. Generalized estimating equations were used to analyze childhood variables, which were assessed every 6 months over the first eight waves of data collection. Due to missing data, there were 391 (interpersonal callousness) and 393 aggressive behavior observations of a possible 448 for childhood outcomes. Complete data were available for 46 adolescent participants.

B, unstandardized regression coefficient; YSR, Youth Self-Report.

[a]Log transformed due to positive skew.

Note: From "Lower Amygdala Volume in Men is Associated with Childhood Aggression, Early Psychopathic Traits, and Future Violence" by Pardini et al., 2014, *Biol Psychiatry*, 75, p. 73-80

6. Conclusion

Most of the research on the effect of ACC and amygdala on criminal behavior are still debatable. One of the study conducted by Dr. Raine indicated that there is no difference in the ACC volume among psychopath with normal people, and still lack of evidence-based level regarding with the activation of ACC affect towards the behavior of an individuals with psychopath characteristics or aggressive behavior, as well as for the study on the effect of activation of amygdala towards an individual criminal behavior. A review on studies related to the topic is significant in the search for significant experimental studies of ACC and amygdala towards criminal behavior and targeted to find out the clear effect of ACC and amygdala on criminal behavior. The current study offers strong support of functional irregularities of the ACC and amygdala in criminals presenting with psychopathic traits. More particularly, findings indicate that psychopathic traits is significantly linked with reduced ACC and amygdala function, especially the right rostral ACC, left rostral ACC, caudal ACC, left amygdala and right amygdala, when compared with healthy subject controls. In summary, the current meta-analysis emphasis the significant need for imaging studies on female criminals with psychopathic and as well examining other possible mediating variables such as impulsivity, emotional alteration, and novelty seeking (Gavita et al., 2012). Several regions other than the ACC and amygdala are probable to be associated in criminal's psychopathic traits. In future, research should aim on those regions of the brain that work intimately with the ACC and amygdala, such as OFC, hippocampus, insula, and angular gyrus (Gavita et al., 2012). These results offer productive ground for more examination targeted at predicting re arrestment and improving therapy for psychopathic criminals. Future neurobiological research is important in integrating neuroimaging, neuropsychological, and behavioral methods as is required to improve future researcher on understanding of the complex mechanisms underlying the externalization of psychopathic traits and eventually offer latest grounds for the expansion of efficient treatments (Gavita et al., 2012)..

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