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**SYSTEMATIC META-ANALYSIS OF THE ROLE EFFECT OF
ANTERIOR CINGULATE CORTEX (ACC) AND AMYGDALA IN
CRIMINAL BEHAVIOR**

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GLORY LAU SIEW TEE

This project is submitted in partial fulfilment of the requirements for a
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“Are not two sparrows sold for a penny? Yet not one of them will fall to the ground apart from the will of your father. And even the very hairs of your head are all numbered. So don’t be afraid; you are worth more than many sparrows.” (Matthew 10: 29-31, New International Version).

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TABLE OF CONTENTS

LIST OF TABLES	viii
LIST OF FIGURES	ix
ABSTRACT	x
ABSTRAK.....	xi
CHAPTER ONE INTRODUCTION	1
Background of the Study	1
Problem Statement	4
Research Objectives	5
General Objective.....	5
Specific Objectives.....	5
Research Question.....	6
Hypothesis	6
Conceptual Framework.....	6
Definition of Terms	7
Anterior Cingulate Cortex (ACC)	7
Conceptual definitions	7
Operational definitions.....	7
Amygdala	8
Conceptual definitions	8
Operational definitions.....	8
Antisocial behavior.....	8
Conceptual definitions	8
Operational definitions.....	8

Aggressive behavior	9
Conceptual definitions	9
Operational definitions	9
Contributions of Study	9
Summary.....	10
CHAPTER TWO LITERATURE REVIEW.....	11
Individuals with Antisocial Behavior	11
Individuals with Aggressive Behavior.....	11
Behavioral Measurements.....	12
(GNG) go/no-go task	12
Pediatric Behavior Scale (PBS).....	12
Hare Psychopathy Checklist-Revised (PCL-R).....	13
Assessed Instrument	14
MRI scanning	14
fMRI scanning	15
Research on Anterior Cingulate Cortex (ACC)	15
Research on orientation of ACC towards antisocial behavior of criminals	16
Research on orientation of ACC towards aggressive behavior of criminals	19
Research on Amygdala	21
Research on orientation of amygdala towards antisocial behavior of criminals	22
Research on orientation of amygdala towards aggressive behavior of criminals	25
Summary.....	27
CHAPTER THREE METHOD	29

Research Design	29
Instrument	30
Data Collection Procedure	30
Literature search	30
Criteria for study selection	31
Variables coded from each study	32
Data Analysis Procedure.....	32
Computational of effect size.....	32
Sensitivity analysis and diagnostics	33
Conclusion	33
CHAPTER FOUR RESULTS	34
Data Collection Stage	34
Evaluation of data	34
Data Analysis Stage.....	39
Procedure.....	39
Coding for potential moderator	39
Data Interpretation Stage	39
Result analysis	39
Moderator analysis	41
Mean effect size	41
Conclusion	42
CHAPTER FIVE DISCUSSION.....	43
Localizations and Lateralization of ACC and Amygdala Impairments	43
Implications of Treatment Strategies.....	45
Limitations and Future Directions.....	46

Conclusions.....	47
REFERENCES	48
APPENDIX DATA USED FOR EFFECT SIZES CALCULATION.....	53

LIST OF TABLES

Table 1 The Demographic, Behavioral, and Structural Information between Boys and Girls.	21
Table 2 Associations between Adult Amygdala Volume and Earlier Aggressive Behavior and Psychopathic Features	27
Table 3 Demographic Information and Sample Characteristics of the Five Studies	36
Table 4 Mean Effect Sizes for the Regions of Interest across the Five Structural and Functional Imaging Studies	39
Table 5 Mean Effect Sizes for 5 Studies	41

LIST OF FIGURES

Figure 1 The independent and dependent variables of the study.....	7
Figure 2 Cox survival function presented proportional rearrest survival rates of high with solid 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 rearrest indicated 25.27 (2.80) mo with overall probabilities of 60% while the high mean survival times to rearrest indicated 32.42 (2.73) mo with overall probabilities of 46%	17
Figure 3 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)	18
Figure 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	23
Figure 5 Amygdala volumes of psychopathy individuals and normal controls, together with total brain volumes as covariate.....	24
Figure 6 General summaries of data in terms of effect sizes across different brain regions for ACC and amygdala, using 95% confidence intervals	40
Figure 7 General summaries of data in terms of effect sizes across five different studies, using 95% confidence intervals	42
Figure 8 Location of rostral anterior cingulate cortex	45

ABSTRACT

Study of brain malfunctioning effects on the behavior of criminal had been carried out ever since 18th century. There are many region of interest of the brain considered to play this important role. Two types of brain regions were used to study in this project, which were 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 emotional processing such as fear, anger and happiness. Meta-analysis method was used to study the role effect of ACC and amygdala towards the behavior of criminals in terms of antisocial and aggressiveness. This method was generally used because it was a statistical technique that can combine segregated independent studies to come out with one stable summarization without prejudices and the net benefit summative over included studies can be estimated. As a result, rostral ACC with -1.44 of effect size and right amygdala with -2.35 of effect size had indicated a higher level of effects 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, which will be discussed further in this project, as well as for future treatment and implementation.

Keywords: anterior cingulate cortex, ACC, amygdala, antisocial behavior, aggressive behavior, psychopath, criminal

ABSTRAK

Kajian tentang kesan kerosakan otak manusia terhadap perlakuan penjenayah sudah bermula sejak abad ke-18. Terdapat pelbagai jenis kawasan otak telah dipercayai memainkan peranan yang penting ini. Dua jenis kawasan otak manusia telah dikaji dalam projek ini, iaitu anterior cingulate cortex (ACC) dan amygdala. Fungsi ACC adalah untuk mengenali kesalahan atau defisit dalam piawaian yang tertentu, membuat jangkaan sebelum melaksanakan sesuatu tugas dan mengawal emosi seseorang, manakala fungsi amygdala pula kepada emosi pemprosesan seperti ketakutan, kemarahan dan kebahagiaan. Kaedah meta-analysis telah digunakan untuk mengkaji kesan peranan ACC dan amygdala terhadap perlakuan jenayah dari segi antisosial dan agresif. Kaedah ini biasa digunakan kerana ia adalah teknik statistik yang boleh menggabungkan kajian yang berasingan dan mengeluarkan satu rumusan yang stabil tanpa prasangka. Tambahan pula, faedah sumatif kepada kajian yang dirangkumi dapat dijangka. Dalam keputusan, rostral ACC dengan saiz kesan -1.44 dan amygdala dengan saiz kesan -2.35 telah menunjukkan tahap kesan yang lebih tinggi berbanding dengan kawasan otak ACC dan amygdala yang lain. Kesimpulannya, kawasan ACC dan amygdala yang berlainan telah menunjukkan tahap yang berbeza dalam memberi kesan terhadap perlakuan penjenayah, dan perkara tersebut akan dibincangkan selebih lanjutnya dalam projek ini, termasuk rawatan dan perlaksanaan pada masa depan.

Kata kunci: anterior cingulate cortex, amygdala, ACC, antisosial, agresif, penyakit jiwa, penjenayah

CHAPTER ONE

INTRODUCTION

In this project, two regions of the brain limbic system was studied, which is the *anterior cingulate cortex (ACC)* and *amygdala*. The activities of these two regions were believed to play an important role in *criminal* minds. Hence, this study becomes important in defining potential *criminal* at the early stage.

Many similar researches had been carried out by other researchers in determining whether the behavior and the possibility of a person involve in future crime especially the released prisoners can be predicted. The study also used to describe and clarify the reason of a *criminal* who fail to control his behavior when doing crime. Once the factors and evidence collected was enough to prove the linkage between the *criminal* mind brain activation and his behavior, *criminal* prevention will be more efficient from happening in future.

Background of the Study

The idea of malfunctioning brain organization effect on *criminal* behavior was proposed by Franz Joseph Gall, who claims to have recognized overdeveloped and underdeveloped brain that will generate a certain personality in 18th century (Adams, 2013). In the middle of 1800s, phrenology had broadly influence in the *criminal* law of both United States and Europe, which was usually used to support rough ethnic as well as group-based typecast of illicit behavior (Adams, 2013).

Study of *criminal* mind then later started in November 1871 in Italy by Cesare Lombroso, a psychiatrist and prison doctor at a refuge for insane *criminal* (Raine, 2013). He performed a regular autopsy on a person named Giuseppe Villella, and found an abnormal groove at the bottom of Villella's skull (Raine, 2013). He proposed a controversial theory with two key points based on this observation: crime started in huge degree from abnormalities of the brain and *criminals* were an evolutionary throwback to more ancient

species (Raine, 2013). The basic physical characteristics of a *criminal* he believed, to have large jaw and sloping forehead, which then by using this traits measurement, created an evolutionary hierarchy, with Northern Italians and Jews at the top, Southern Italians (like Villella), Bolivians and Peruvians at the bottom (Raine, 2013).

This pseudoscientific phrenological theories regarding the shape and size of the human head, thrive throughout Europe in late 19th and early 20th centuries, but this theory then turn out to be socially and scientifically devastating, unanimously encouraging human beings not worth to reproduce or to live (Raine, 2013). Lombroso's theory no longer applicable after World War II and became feature more on to economic, political factors or psychological disturbances, not to biology (Adams, 2013).

However, Lombroso's highlight on physiology and brain traits has verified to be prophetic (Raine, 2013). Recent scientist now had developed a more convincing argument for genetic and neurological mechanism of *criminal* behavior by using neuroscience to recognize and avert crime (Raine, 2013).

To identify physical deformations and functional abnormalities that prompt individuals to violence, brain-imaging techniques are used (Raine, 2013). In one recent study conducted around 2007 by Kent Kiehl, a neuroscientist at non-profit Mind Research Network in Albuquerque, New Mexico, he and his coworker take a sample of 96 male prisoners for research just before they were released (Nuzzo, 2013). Functional magnetic resonance imaging (fMRI) were used to scan the prisoners' brains the moment they were doing computer task where participants need to make rapid decisions and restrain impulsive responses (Nuzzo, 2013).

The small region of *anterior cingulate cortex (ACC)* in the front of the brain was focused via scans, which play an important role in motor control and executive functioning (Nuzzo, 2013). The *ex-criminal* was then continuously followed for four years by the

researcher to observe how they charged (Nuzzo, 2013). Among these participants, men with lower activity on ACC when doing rapid decisions tasks were more prompt to being arrested again after released from prison, although researchers accounted for other possible consequences like age, drug, alcohol abuse and *psychopathic* features (Nuzzo, 2013). Men with lower half of ACC activity ranking had 2.6-fold higher degree of being rearrested for all crime and 4.3-fold higher degree for non aggressive crime (Nuzzo, 2013).

In another study carried out in 2009, Yaling Yang, Adrian Raine and his colleagues conducted a brain scan on 27 *psychopaths* that was found in temporary-employment agencies in Los Angeles (Raine, 2013). *Psychopaths* score high scores on Psychopathy Checklist present these personality features such as lack of guilt, insensitivity and pretentiousness (Raine, 2013). For results, when compared with 32 normal people in the control group, *psychopath* group was found to have 18% smaller *amygdala* which plays vital role in human emotions such as fear and partly with the neural circuitry fundamental for decision making in moral (Raine, 2013).

Consequently in the same year, King's College neuroscientists carried out a research that studies the region of brain which was responsible towards self-control and aggressive level of an individual by using diffusion tensor of MRI in London (Menting, 2011). Among the *psychopaths*, these regions are appearing to be deviant (Menting, 2011). It was found that the area of white matter in the section connected with *amygdala* which directs the human emotional reaction, and with orbitofrontal cortex that is responsible for the capacity of human decision-making among these people were unbalance (Menting, 2011). Individual that shows severe forms of *psychopath* had even more superior level of this deviation in these brain regions (Menting, 2011).

In summary, these researches have indicated that *antisocial behavior* and *criminal* activities can be explained through biological factors in the aspects of neuroscience.

Problem Statement

A wide-ranging of neurocriminology study based on biological concept such as neuroscience and genetic relationship had been conducted over the years. However, the region of the brain that is responsible on *criminal* activities is still debatable, as the working of brain neurons either works independently or dependently is still remain unknown until now. The main key regions of brain in *criminal* minds, or other terms they called *psychopath* to be functionally and structurally damaged include dorsal and ventral areas of prefrontal cortex (PFC), *amygdala*, hippocampus, angular gyrus, *anterior cingulate cortex* and temporal cortex (Raine & Yang, 2006). There were other brain regions that had been studied as well such as ventromedial prefrontal cortex (VMPFC), frontopolar cortex (FPC), and corpus striatum.

Currently, there were huge literatures that files up the connections between *criminal* behavior and biological functioning (Glenn & Raine, 2014). As many studies had been carried out declaring or disproving the relationship of certain brain regions in *criminal* behavior, clinicians and researchers become more difficult to evaluate and follow up the evidence that was accumulating on the issue (Vassos et al., 2014). There were various approaches, evaluations, region of studies, and types of brainwaves that had conducted in each study, which yield a slightly different result in the end although the purpose is the same.

Furthermore, brain scan analysis on *criminal* mind is seldom carried out because of the inaccessible instrument and costly experiment, which these instruments such as fMRI scan and electroencephalography (EEG) give more priority use on obvious brain damage caused in accident, a person who falls into coma, sudden acute pain on someone's head, schizophrenia and autism patients.

According to Searbook (2008), little research was done to study about *psychopath* by the mental-health establishment. Kiehl indicated that the increasing rate of crime over the

years led no increment of funding in research among *psychopath* but more on to Schizophrenia (Searbook, 2008). This is because schizophrenic patients are often seen as victims to feel empathy for but *psychopaths* are seen as predators to imprison with, which is quite frustrating as both conditions are mental illness but are treated differently (Searbook, 2008).

Hence, review for the studies of which brain areas that influence the *criminal* mind is required. As *anterior cingulate cortex (ACC)* was well known of playing important role on impulsive behavior, *amygdala* for fear, the review will be focus on these two brain regions. However, conservative methods of literature review might cause certain objectiveness of the findings in the review to loss. In addition, there is a risk where researchers may bias or special preferences on every study that affect the result accuracy in the effect of *ACC* and *amygdala* on *criminal* minds.

Therefore, a systematically review from previous studies through meta-analyses is required to understand and find out the evidence based result of the effect of *ACC* and *amygdala* on *criminal* behaviors.

Research Objectives

General Objective

The general objective of this research is to review the effect of *ACC* and *amygdala* on individuals with *criminal* behaviors.

Specific Objectives

The specific objective of this research includes;

- i. To review the specific region part of *ACC* that effect on *criminal antisocial* and *aggressive behaviors*.
- ii. To review the specific region part of *amygdala* that effect on *criminal antisocial* and *aggressive behaviors*.

Research Question

This research is focused on mainly one research question. What is the overall effect of *anterior cingulate cortex (ACC)* and *amygdala* on *criminal* mind? The main research question is then followed by 3 specific research questions:

- i. Which specific region part of *ACC* will effect on *criminal antisocial* and *aggressive behaviors*?
- ii. Which specific region part of *amygdala* will effect on *criminal antisocial* and *aggressive behaviors*?

Hypothesis

The hypotheses that are generated from the previous studies and the objective of the study are:

- H₀₁: There is no difference between any particular region part of *ACC* and the effect of *antisocial* and *aggressive behaviors* among *criminals*.
- H_{a1}: There is a difference between any particular region part of *ACC* and the effect of *antisocial* and *aggressive behaviors* among *criminals*.
- H₀₂: There is no difference between any particular region part of *amygdala* and the effect of *antisocial* and *aggressive behaviors* among *criminals*.
- H_{a2}: There is a difference between any particular region part of *amygdala* and the effect of *antisocial* and *aggressive behaviors* among *criminals*.

Conceptual Framework

The figure below shows that the specific regions of *anterior cingulate cortex (ACC)* and *amygdala* (Independent Variable) have a direct relationship with *criminals' antisocial* and *aggressive behavior* (Dependent Variables).



Figure 1. The independent and dependent variables of the study.

Definition of Terms

Anterior Cingulate Cortex (ACC)

Conceptual definition. *Anterior cingulate cortex (ACC)* is a component of the brain limbic system (Bush et al., 2000). It is also known as Area 25, an area situated towards the front of corpus callosum, in the medial frontal lobe (Moss, 2009). This section is responsible in decision making, regulating emotions, and is significant in regulating psychological process such as blood pressure and heart rate (Moss, 2009). The key functions for *ACC* are:

- Faults or deficits recognition from certain standards
- Expectation and preparation before task presentation
- Emotional regulations (Moss, 2009)

Operational definition. According to Miller (2014), *ACC* plays an important role in directing behavior and impulsivity, which connected with crime. Functional neuroimaging studies by using positron emission tomography (PET) scan indicated the activation of *ACC* throughout the task that involve selective attention, working memory, language production, and controlled information processing (Cabeza & Nyberg, 1997). Individuals with lower activation of *ACC* were twice as likely to involve in crime compared to individuals with higher activation of *ACC* (Miller, 2014).

Amygdala

Conceptual definition. *Amygdala* is an almond-shape set of neurons situated deep in the brain's medial temporal lobe, form as a part of the limbic system that plays an important role in handling emotions and motivations, which is mostly connected with survival (Bailey, 2014). *Amygdala* is engaged in emotion processing such as fear, anger, and delight, as well as accountable for influencing the type and the position of memories to be stored (Bailey, 2014). It was believed that the impact of emotional reaction towards an event will determine the storage of memories (Bailey, 2014).

Operational definition. *Amygdala* is involved in autonomic reactions connected with terror and secretions of hormone, and was discovered to be responsible in fear conditioning through a scientific study (Bailey, 2014). According to Miller (2014), *amygdala* as a part of the brain that engage in fear, violence and social relations is linked with crime. An individual with lower *amygdala* volumes are three times more likely to behave aggressively and violent, as well as shown *psychopathic* features after some time compared to individuals with normalized *amygdalas* (Miller, 2014).

Antisocial Behaviors

Conceptual definition. *Antisocial behaviors* are disturbing action featured by hidden and explicit hostility and deliberate aggression toward other individuals (Hanrahan, 2014). *Antisocial behaviors* presented along a cruelty range and involve repeated defiance of social rules, against authority, abuse the right of others, dishonesty, burglary, and irresponsible towards self and others (Hanrahan, 2014).

Operational definition. *Antisocial behavior* can be identified among children around the age of 3 or 4 years old (Hanrahan, 2014). It is one of the dependent variable in this study, where the scope was generalized due to the various sub-domain used in different studies.

Aggressive Behaviors

Conceptual definition. *Aggressive behavior* is an action that causes physical or emotional harm towards others, as well as threatening with someone (Gabbey, 2013). It can be ranged from verbal abuse to destruct a victim's personal property (Gabbey, 2013).

Operational definition. Individuals with *aggressive behavior* are more likely to be irritable, impulsive, and restless (Gabbey, 2013). *Aggressive behavior* is one of the dependent variable in this study where the scope of the variable is generalized due to the varied sub-domain used in different studies.

Contribution of Study

There is an increasing view of *criminal* behavior and violence as universal health problem (Glenn & Raine, 2014). Lots of study had presented the evidence of neurological basis on *criminal* behavior and gives rise to several vital subjects such as: suggesting the application used to predict future *criminal* behavior to safeguard our civilization, whether it can be used to avert aggression and proposing a suitable way to punish the lawbreaker (Glenn & Raine, 2014).

Comprehension of the knowledge on how the biology factors effects on human behavior had enhanced through the advance in neuroscience, where techniques and principle that are applied in neurocriminology had improved the understanding of crime, predict crime and eventually prevent crime (Glenn & Raine, 2014). This approach will probably provide economic and social benefits which are connected with the minimization of violence, but may raise certain concern regarding with neuroethical issues (Glenn & Raine, 2014).

Anterior cingulate cortex and *amygdala* had been widely proven to have great impact on the effect of *criminal* behavior. Likewise, overview of these studies is provided to serve strong evidence in proving the effects of these brain regions. In addition, this study can provide a stepping stone for further discussion in future studies.

Summary

This research is targeted to study the effect of *anterior cingulate cortex (ACC)* and *amygdala* on the behavior of a *criminal* where this study can be used to identify possible *criminals* and to reduce violence in the society through suitable method in the future.