Neurological Differences in the Prefrontal Cortex, Amygdala, and Lateralization in Criminal Minds

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Abstract

Criminals often portray very abnormal behaviors when compared to normal individuals. The purpose of this literature review is to examine different brain areas to see if any underlying causes of criminality can be identified. The prefrontal cortex, amygdala, and brain lateralization were all studied and examined and it was found that deficits to all three of these areas can cause extreme social, emotional, and cognitive deficits that can result in criminal behavior. It was found that many behaviors are actually controlled by the same areas or that deficits to different areas can produce very similar abnormal behaviors. The current research of how these areas are associated with these specific behaviors is explored and potential repercussions of these findings are also talked about.
A lot of today’s society is fascinated by the minds and behavior of criminals. People love learning about why they do what they do and how they are able to do it without feeling remorse for their actions. The answer to this is hidden in their neurobiology. While some criminals appear to have normal cognition and no abnormalities in their brains, this is typically not the case. It has been reported that over 60% of criminals have suffered from a head injury at some point in their life (The Telegraph). This shows how detrimental head trauma can actually be to a person's life. While direct head trauma can lead to criminal behavior, sometimes people are born with the abnormalities that cause them to exhibit criminal behavior.

The PFC is an area of the brain that is responsible for a lot of higher level cognitive processes. It deals with the executive functions of impulse control, moral judgement, decision making, focusing attention, predicting consequences, managing emotional responses, aggression, personality, and many other things. If the PFC suffers an injury or has a structural or functional defect, it can result in individuals displaying those behaviors and personality traits which in turn, can cause them to engage in actions that are considered criminal. The PFC has several connections to other brain areas, such as the amygdala or the cerebellum, and alterations to the PFC could in turn affect these areas as well and cause abnormalities in the functions that those areas control for (Leutgeb et al., 2015; Taber-Thomas et al., 2014; Camille et al., 2004).

The amygdala is an area of the brain that is a part of the limbic system and is strongly associated with the processing of negative emotions such as anger and fear. It is often studied in the context of fear because in an individual who has no amygdala abnormalities, the amygdala will have high reactivity to something that the individual finds fearful. For example, if an
individual has a phobia of snakes when they see a snake they would have high amygdala reactivity because the snake is associated with fear. Fearlessness is a personality trait that can be associated with criminals because amygdala abnormalities cause them to have a deficit in processing fear (Larson et al. 2013).

Lateralization in the brain is important for a lot of functional processes. For starters, whether you are right-handed or left-handed depends on the lateralization in your brain and whether you are right brain dominant or left brain dominant. Language processing and production is also lateralized to the left side of our brain, indicating that there are important associations with lateralization. There has also been research done that looks into whether or not men and women have lateralization differences in their brains. The research in this literature review digs deeper into the topic of lateralization and whether or not it abnormalities in lateralization can cause criminal behavior. One other important aspect of lateralization is the function of the corpus callosum. The corpus callosum is the main white matter tract in the brain that connects the two hemispheres and passes information from one to the other (Raine et al., 2012). There are several other white matter tracts in the brain that connect different areas to each other because while different brain areas have different functions, it can take multiple areas to complete one task. Damage to the white matter tracts in the brain could potentially have huge implications for criminal behavior.

Psychopathy is strongly associated with criminal behavior. It is characterized by deficits in different behavioral traits such as callousness, fearlessness, lack of empathy, lack or remorse, violence, impulsivity, dishonesty, antisocial behavior, etc. (Leutgeb et al., 2015). Most of the studies looked at in this review tested the participants to see if they were psychopaths. The Psychopathy Checklist-Revised (PCL-R) is a test that was developed to be a measure of
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psychopathy in individuals and it was used in most of the studies presented in this review. It includes 20 different items all of which are rated on a three-point scale. If an individual scores about a 23 or higher then they are considered a psychopath. Scores less than 23 are typically just associated with psychopathic behavior. The PCL-R is further broken down into two different factors. Factor 1 scores are correlated with grandiosity, callousness, manipulation, increased sense of self-worth, lack of remorse, etc. while factor 2 scores are associated with impulsivity, lack of realistic long term goals, and antisocial behavior such as behavioral problems and poor behavior control (2015).

The purpose of this literature review is to determine the neurological abnormalities that play a role in criminal behavior. This literature review summarizes studies about the PFC, amygdala, and brain lateralization to try and determine how the abnormalities presented in these brain areas cause individuals to partake in abnormal behavior that is typically present in criminals. It attempts to connect all the different findings talked about in the studies to try and connect the abnormalities together and determine how they interact to produce these criminal behaviors.

Prefrontal Cortex

One of the main areas of the brain that is often associated and studied in individuals who exhibit criminal behavior is the prefrontal cortex (PFC). This is because the PFC is responsible for higher level processing such as attention, impulsivity, emotion control, and regret. Lots of research has been conducted in this brain area using MRI and fMRI in order to compare the PFCs of convicted criminals to normal individuals in order to determine what the differences are. One difference that will be investigated is the amount of grey matter volume (GMV) that the PFC has in the brain because studies have reported that this differs in brains of criminals and a
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decrease in the (GMV) could lead to processing deficits in certain emotional and behavioral aspects of individuals and play a role in the potential etiology of some neurological disorders (Leutgeb et al., 2015).

The developmental aspect of the PFC will also be investigated because it plays such a large role in the emotional and social development of individuals and a disruption in development could be a potential cause for the aspects of criminality that cause individuals to engage in that behavior (Taber-Thomas et al., 2014). Some behavioral aspects of the PFC function will also be looked at, impulsivity and regret. Both of these functions are controlled and regulated by the PFC in normal and healthy individuals and these two behaviors are also typically abnormal in criminals. Studies have broken down these two behaviors and shown how they are compromised in the minds of criminals because of the different abnormalities to areas in the PFC that cause these functions to be dysfunctional.

A study by Leutgeb et al. (2015) compared the structural differences in the brains of high-risk violent offenders with the brains of non-delinquent controls. It was predicted that a negative correlation would be found between the grey matter volume (GMV) in the PFC with the PCL-R scores of criminals because the PFC is responsible for the neural processes of moral thinking and reasoning along with decision making, functions that are usually compromised in criminals. The results supported the hypothesis and showed that as criminals reported higher scores on the PCL-R, they showed decreased GMV in their PFC. The results also showed that the factor 1 scores on the PCL-R had a negative correlation with the GMV of the PFC, so as the factor 1 scores went up the GMV tended to decrease. Since factor 1 of the PCL-R is associated with emotional deficits, like the PFC, it makes sense that a decrease in GMV of the PFC would
DIFFERENCES IN PFC, AMYGDALA, AND LATERALIZATION cause these types of selfish and callous traits in psychopaths who had high factor 1 scores (Leutgeb et al., 2015).

Another study also looked at structural differences in the PFC of criminals except it compared the GMV and cortical thickness of the PFC in unsuccessful psychopaths and successful psychopaths. Unsuccessful psychopaths are defined as criminals who scored a 23 or higher on the PCL-R and were convicted for crimes they committed while successful psychopaths scored a 23 or higher on the PCL-R but were not convicted for crimes they committed (Yang, Raine, Colletti, Toga, & Narr, 2010). The results from the participants MRI scans showed that the unsuccessful psychopaths had significant GMV reductions in the right medial PFC and the orbitofrontal cortex (OFC) when compared to controls and in the right medial frontal cortex and the left OFC when compared to successful psychopaths. The unsuccessful psychopaths also had significant reductions in cortical grey matter thickness across the entire hemisphere of the PFC but specifically in the right medial PFC and OFC (Yang et al., 2010). Yang et al. (2005) also looked at structural differences in the PFC of unsuccessful psychopaths and found that when compared to controls, unsuccessful psychopaths had a 22.3% volume reduction in their prefrontal grey matter and an overall lower whole brain volume. As seen in the Leutgeb et al. (2015) study, these results also showed a negative correlation between the PCL-R scores of criminals and prefrontal GMV (Yang et al., 2005).

Antisocial Personality Disorder (APD) is also typically associated with structural differences in the PFC of individuals and is often a disorder that criminals possess. Raine, Lencz, Bihrlie, LaCasse, & Colletti (2000) looked at the PFCs of individuals who had been diagnosed with APD and compared them against the structural MRIs of controls and found that the APD group had an 11% reduction in PFC grey matter when compared to the whole brain. The
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Participants also took part in a social stressor where they had to present a speech that highlighted their individual faults. The participants with APD also showed significantly reduced autonomic activity, mainly skin conductance, during the social stressor when compared to the control groups (Raine et al., 2000). A relationship between the PFC GMV and skin conductance can be explained due to the fact that the PFC is also involved in arousal. Since the individuals in this study were found to have less GMV in the PFC, the fact that they had reduced autonomic activity makes since because they have a deficit in the brain area that controls the mechanism. The APD group most likely also had decreased autonomic arousal because of other functions associated with the PFC. Since the PFC is also associated with the executive functions of decision making, planning, and evaluating risk, if the PFC has a structural abnormality and these functions become impaired, it could predispose individuals to suffer from these deficits and display certain behaviors that are associated with APD (Raine et al., 2000).

While many structural differences have been found in the PFC of criminals, there are also significant functional differences that have been found. A study by Choy, Raine, & Hamilton (2018) looked at the effects of stimulating the dorsolateral PFC using a technique called transcranial direct current stimulation (tCDS) and whether it would reduce the likelihood of people committing aggressive acts. They took 86 healthy participants and used a double-blind experimental design to randomly assign the participants to the control to receive the tCDS or to the placebo group. The participants took part in a cognitive task that engaged the dorsolateral PFC and were asked to rate how likely they were to commit physical or sexual assault on a scale of 1-10, to rate for aggression, and they were also asked to rate how morally wrong they believed these acts to be. The results showed that the participants who received the tCDS treatment to the dorsolateral PFC were less likely to commit the aggressive acts and also reported them as being
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more morally wrong than the control group (Choy et al., 2018). These results are an important discovery because it could lead to a potential treatment path for aggressive individuals that have a tendency to commit criminal acts.

In regard to the idea of something being morally right or wrong, the ventromedial PFC has a major relationship to proper moral development in individuals. Taber-Thomas et al. (2014) took a group of individuals who suffered ventromedial PFC injuries before the age of 16 and a group who suffered ventromedial PFC injuries closer to adulthood. The participants judged a series of moral conflicts that were either high conflict or low conflict. The high conflict scenarios presented participants with a choice that would challenge their personal or utilitarian considerations, for example, smothering a crying baby to save a larger group of people. The low conflict scenarios did not have quite as high of a personal or utilitarian conflict, for example, lying to save others from some sort of physical harm. The results showed that the patients who suffered childhood ventromedial PFC injuries were more likely to choose the self-serving and personal moral actions over the utilitarian options when they assessed the high moral conflict, while the patients with the ventromedial PFC injuries that occurred later in life tended to not choose the self-serving actions and were more likely to choose the utilitarian action (Taber-Thomas et al., 2014). This demonstrates how important it is for the proper development of the ventromedial PFC because proper moral development is important for social and personal development. By identifying this key development issue, research could be done to try and development treatment options for children who suffer ventromedial PFC injuries so they will have proper moral development and potentially decrease the risk of them committing aggressive and violent acts and going to jail.
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Another key defining personality trait of criminal behavior is poor impulse control. A study done by Tsutsui-Kimura et al. (2016) looked at the conditions of impulse control in rats by looking at their infralimbic cortex, located in the medial PFC, and having them perform a three-choice serial reaction time task that tests for animal impulsivity. The rats were injected with muscimol, a GABA receptor agonist that helps briefly impair their impulse control, and then redid the three-choice serial reaction time task. The results of this experiment showed that inhibiting the infralimbic cortex caused an increase in the number of premature responses indicating a disruption in their impulse control (Tsutsui-Kimura et al., 2016). Similar results have been seen in human studies. One experiment took a group of 20 healthy participants and 14 psychopathic criminals and had them participate in a monetary incentive delay task, to measure impulsivity, where they were presented with a cue that was followed by a blank screen and a white circle (Geurts et al., 2016). When the participants were presented with the white circle, they were instructed to press a button as quickly as possible. If the participants hit the button fast enough, they would gain a point if they were in the reward condition but would not gain a point if they were in the no reward condition. To further incentivize the participants, they were told that their points would be converted to a monetary value at the end of the experiment. The results showed that there was a greater Blood Oxygen Level (BOLD) signal in the ventral striatum in the reward condition and in the group of criminals with high antisocial and impulsive behavior scores. This result is significant in terms of PFC differences because the ventral striatum sends information to the PFC to help us make decisions depending on what the outcome of the decision might be. The purpose of the previously mentioned experiment was to study the reward expectation in criminal who scored high on the antisocial and impulsivity sections of the psychopathic personality inventory (PPI) (Geurts et al., 2016). The results found are important
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because once again they could help us identify a neurological abnormality that is potentially
common in criminals that have high reports of impulsivity and this could potentially help lead us
to future treatment options.

One study looked at another aspect of impulsivity, response inhibition. This study used an
extensive neuropsychological test battery that measured response inhibition, planning, attention,
set-shifting, working memory and impulsivity/reward sensitivity in 130 male prisoners. The
participants all took part in the Stop-Signal Task (SST) that measured their response inhibition.
The SST used a pad that has two buttons and instructs the participants to press either the left or
the right button as fast as they can depending on which way the arrow is pointing on the screen
(Meijers, Harte, Meynen, & Cuijpers, 2017). The participants are then instructed to do the same
thing except this time they are supposed to stop pressing the buttons all together if they hear a
loud beep. The results of this study showed that the violent offenders had worse scores on the
stop-signal task, meaning it took them longer to stop pressing the button than the non-violent
offenders. Because the violent offenders showed lower response inhibition scores compared to
non-violent offenders, this suggests a more pronounced deficit in the PFC of violent offenders
than non-violent offenders and that violent offenders have reduced inhibition (Meijers et al.,
2017).

Another area in the PFC that can have abnormalities that have been shown to cause
impairments associated with criminal behavior is the orbitofrontal cortex (OFC). The OFC has
major connections to parts of the PFC and has a role in the functions of reasoning, planning,
and reward evaluation and comparison (Camille et al., 2004). One study looked at this,
specifically the OFC and the experience of regret. The study took individuals with OFC lesions
or injuries and healthy control subjects and had them participate in a gambling task where they
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were presented with a choice. In one of the tasks, the participants would be able to see the outcome of the option they chose and the option they did not choose while in the other task the participants were only able to see the outcome of the option they chose. The participants rated how happy they were with the outcome of the option they chose on a scale of 1-10. The results of the experiment showed that the patients with the OFC lesions or injuries did not report any regret in their decision, even if the outcome of the option they did not choose was better than what they ended up with, while the control participants were typically not as happy with their choice if the other option was better (Camille et al., 2004). These results help demonstrate that the OFC is necessary for being able to feel regret and is potentially a predictor that someone will grow up to display criminal behaviors and maybe some treatment that could be developed to try and help prevent this.

Another study also looked at the experience of regret but instead looked at the ventromedial PFC and lesions in this area (Kraibich, Adolphs, Tranel, Denburg, & Camerer, 2009). The study took six patients that had focal bilateral damage to the ventromedial PFC, 20 patients with focal and stable lesions in other areas of the brain, and 16 healthy patients and had them participate in three games, dictator, ultimatum, and trust, that were used to measure social preferences in economics. In the dictator game the participants divided 50 points between themselves and a stranger, if they gave more than zero points to the stranger then this showed that they would experience some sense of guilt since they did not keep all the points for themselves. In the ultimatum game the participants played the game twice, once as the proposer and once as the recipient. When they played as the proposer, they were asked how many points they would offer and when they played as the recipient they were asked what was the minimum amount they were going to ask for. If the participants rejected the offers presented to them this
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was perceived as a sign of envy. In the trust game one of the players, the investor, can end the
game which would allow both players to receive 20 points or they could choose to trust the other.
If the investor chooses to trust the second player, they then get to decide if they want to repay the
first player or betray them (Krajbich et al., 2009). The results showed that in the dictator game,
the patients with the ventromedial PFC lesions gave significantly less points than the controls,
indicating their lack of guilt. In the ultimatum game, it was seen that the lesion subjects
demanded significantly more than they were willing to offer, once again indicating their lack of
remorse. In the trust game, the lesion patients choose the trust option way less than the controls
and if they were the second player, they repaid the other player way less than the controls did.
This study shows how the ventromedial PFC is associated with the emotions of guilt and how
lesions to this area causes a significant defect in individuals being able to process these feelings
or being able to empathize with the other participants to see how they would feel if they were the
one being cheated out of points (Krajbich et al., 2009).

Based on the literature reviewed above it is evident that there is a defined relationship
between the PFC and criminal minds. It was shown that damage to the PFC causes individuals to
exhibit qualities of abnormal emotion regulation, aggressive behavior, improper moral reasoning,
impulsivity, and lack of remorse. The studies showed that as damage to the PFC got more
intense, that the criminal behavior increased more and that the individuals who suffered from
these deficits exhibited less and less awareness of certain social factors which also increased
their chances of getting arrested. They also began to express more violence and aggression,
sometimes without experiencing any type of regret. It was also seen that the PFC has a
correlation with certain aspects of psychopathy due to the fact that factor 1 scores and PFC
volume were negatively correlated. Although it was seen that there were high correlations
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between the PFC and these certain deficits in behaviors, it is impossible to label exactly what
deficits cause criminals to act this way since the PFC also has so many connections to other areas
of the brain that process emotions. However, because of these studies, important aspects of the
potential etiology of criminal behavior were identified and there can be more warning signs for
the potential predisposition of criminal behavior and action can be taken to try and prevent
individuals from turning into dangerous criminals.

Amygdala

The amygdala is a part of the brain that is associated with a lot of negative emotions such
as sadness, fear, threat, anxiety, and anger. If the amygdala is functioning properly in individuals,
then the emotions can be a good defense mechanism for threatening situations and how to
respond to them. However, if there are abnormalities to the amygdala they can have behavioral
modifications that can have a negative impact on an individual and cause them to commit
criminal acts. For example, studies have shown that abnormal amygdala structure and function
can have a potential impact of an individual developing APD or exhibiting those types of
behaviors and this is explored more in the following research (Yang, Raine, Colletti, Toga, &
Narr, 2010; Dotterer, Hyde, Swartz, Hariri, & Williamson, 2017). The main emotion that the
amygdala processes however is fear. The amygdala is the center of the fear network and
abnormalities to this have presented deficits not only in having a fear response, but also in being
able to process other people’s fear. Sometimes, the amygdala can have excessive reactivity and
even cause people to be more violent because they have a heightened reaction to threats
(Coccaro, McCloskey, Fitzgerald, & Phan, 2007). These amygdala abnormalities seem to have a
correlation with criminal behavior and are investigated in the research presented.
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One study looked at the structural differences of the amygdala between unsuccessful psychopaths, successful psychopaths, and healthy control subjects (Yang et al., 2010). The results showed that there was a difference in both the right and the left amygdala across all three groups. In the left amygdala, unsuccessful psychopaths showed a volume reduction of 26% while the successful psychopaths showed a volume reduction of only 9.3%. In the right amygdala there was a 20% volume reduction for unsuccessful psychopaths while the successful psychopaths only saw a 12.7% reduction. These abnormalities in the amygdala may suggest that there are actual deficits that may predispose whether psychopaths will be successful or unsuccessful because the deficits in these amygdala areas can lead to increased risky behavior and also prevent them from being able to process social and emotional cues involved in avoiding criminal conviction (Yang et al., 2010).

Another study investigated the structural differences in the brains of individuals with schizophrenia and APD, since these two disorders are the two that are typically associated with violent criminal behavior. The study compared neural images of men with schizophrenia and APD compared with controls. To test for the influence of violence, the schizophrenics were split up into groups of violent schizophrenics (VS) or non-violent schizophrenics (NVS). A significant difference was found in the size of the amygdala, with the NVS and VS groups having reduced amygdala volume when compared to the other two groups, but there was no difference found between the VS and NVS themselves (Barkataki, Kumari, Das, Taylor, & Sharma, 2006). There was no difference found in the size of the amygdala in the APD group, which potentially shows that the amygdala could be related to certain biological aspects of schizophrenia and even be a cause of the neurological disorder (Barkataki et al., 2006).
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While the previous studies showed no structural amygdala deficits that were associated with APD, other research has shown that there are abnormalities in the amygdala that are associated with certain antisocial behaviors. In order to investigate the relationship between the amygdala and antisocial behavior, adolescents with non-clinical levels of antisocial behavior were studied using a perceptual face processing task that was designed to elicit substantial amygdala activity (Dotterer et al., 2017). The participants were instructed to look at a trio of faces that expressed either anger or fear and then pick the face that matched the target stimulus. They then did the same thing with shapes as a control task. The results showed that antisocial behaviors were significantly related to increased reactivity in the right amygdala when the participants looked at angry faces, specifically in the right basolateral amygdala when the angry facial expressions were shown and matched. It was theorized that this increase in reactivity to the angry faces because they are threat related cues and individuals with APD process them as more threatening than normal individuals which is why they might react more aggressively and impulsively (Dotterer et al., 2017).

Another potential predictor for criminal behavior is a specific oxytocin receptor found in antisocial men that could help predict variability in amygdala function. This was seen in a study by Waller et al. (2016) when they examined whether oxytocin receptor (OXTR) polymorphisms would be linked to threat-related amygdala activity. They took 406 18-22 year olds and genotyped them using their DNA. The participants then took part in a face matching and shape matching task that would evoke significant amygdala activation. The faces shown displayed either angry, fearful, surprised, or neutral emotions and the participants were asked to pick the two faces that matched the target stimulus that was also presented. The participants were asked to do the same thing with the shapes. The results found that men with the OXTR T allele had
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significantly higher right amygdala reactivity when looking at the angry faces (Waller et al., 2016). This finding predicted higher antisocial behavior in men with this trait but not women, indicating that there could be a sex difference. A similar finding was also found with men with impulsive behavior having significantly higher amygdala reactivity when looking at angry faces than women (Carre`, Hyde, Neumann, Viding, & Hariri, 2012). These findings suggest a sex specific and genetic relationship between men and antisocial behavior or traits associated with it.

A different study looked at the association between the amygdala and the OFC in emotional regulation and impulsive aggression or intermittent explosive disorder (IED) (Coccaro et al., 2007). Ten unmediated participants with IED and ten control participants were instructed to look at emotionally salient faces while in an fMRI machine so the specific regions of the brain could be compared and examined based on levels of aggressive behavior. The fMRIs showed that when looking at the angry faces, the participants with IED showed increased amygdala activity and decreased OFC activity, but they failed to show amygdala and OFC functional connectivity while looking at the angry faces when compared to the controls. The increased amygdala reactivity in patients with IED when they view the angry faces shows that these patients see the angry face as a direct threat to them, which is why in some cases they can get extremely violent (Coccaro et al., 2007). Also, since there is a deficit in the connectivity of the amygdala and OFC normal functioning of emotion regulation and aggression control are compromised and contribute to this abnormally aggressive behavior too (Coccaro et al., 2007).

There have also been other reports of abnormal amygdala connectivity in individuals who express criminal behavior. One study took 230 violent and nonviolent individuals and randomly presented them with pictures of neutral and fearful faces randomly. They found that there was a
smaller fear/neutral (F/N) difference and grey matter concentration in the left amygdala that was
caused by an increased reactivity to neutral faces in the violent participants (Bobes et al., 2012).
The F/N difference is the calculated difference between the participants’ responses to fearful and
neutral faces. It was also reported that the F/N difference was negatively correlated with reactive
aggression traits. This type of amygdala abnormality has also been seen in children with early
onset conduct disorders and children with pediatric bipolar disorder, so even though this was one
of the first times they saw this pattern in adults it's not completely unheard of (Marsh et al.,
2008). This suggests that there could be anatomical anomalies in the circuitry of the amygdala
hyper-reactivity correlated to social signals, a characteristic of reactive aggression (Bobes et
al., 2012).

Leutgeb et al. (2016) also looked at altered amygdala connectivity in aggressive violent
offenders. They took non-psychopathic male prisoners that were classified as high-risk violent
offenders and took resting-state functional connectivity (RS-fc) MRI scans and compared them
against scans of non-criminal offenders to look at the connectivity of the amygdala to other areas
of the brain. Results showed there was increased RS-fc between the right cerebellum and the left
amygdala in the high-risk violent offender group (Leutgeb et al., 2016). The connection between
the cerebellum and amygdala is associated with the regulation of emotional functions so an
abnormality in this connection could cause the abnormal functioning that could lead to impulsive
or violent criminal behavior as well as disfuntion in the processing of moral emotions (Leutgeb
et al., 2016).

The amygdala has a lot of connections to other areas in the brain as well and
abnormalities to these connections can cause certain abnormalities in behavior. A study took a
group of 18 violent criminals and 26 non-violent criminals and had them participant in a point
DIFFERENCES IN PFC, AMYGDALA, AND LATERALIZATION subtraction aggression paradigm (PSAP) that looked at neural responses to provocations and aggression. In the PSAP, the subjects are provoked by a fake opponent that steals their money and the subject can react by acting aggressively or by pursuing monetary rewards (da Cunha-Bang et al., 2017). The subjects spent 12 minutes on the PSAP and they could respond to the actions of their opponent by pressing a button. If they pressed the button for option 1, the participant would earn one point. If they pressed the button for option 2, then a point would be taken away from their opponent. If they pressed the button for option 3, the participants’ points were protected from being stolen by the opponent. To test for aggression, the subjects in the experimental group were told that they could not keep any of the points they stole from the opponent, but that the opponent would get to keep any of the points they stole from them. This made Option 2 an aggressive response so aggression could be tested in the subjects. The results showed that violent criminals actually had more activity in the amygdala and striatum than the non-violent criminals and the controls (da Cunha-Bang et al., 2017). This increase in response in the amygdala can be further explained by another study by Carre, Hyde, Neumann, Viding, & Hariri, (2013) where they found that an increased response in the amygdala occurred when the participants, who reported high levels of psychopathy, viewed angry faces as threats. In the da Cunha-Bang et al. (2017) experiment, the threat was the opponent stealing the participants’ points, so it would make since that there would be an increased reactivity level in the amygdala of violent psychopaths based on the Carre et al. (2013) experiment.

Another important function of the amygdala is its relationship to fear and fear conditioning in humans. When looking at criminal psychopaths, there have been studies that have shown abnormalities in the circuitry that is responsible for fear and fear conditioning. For example, Birbaumer et al. (2005) took 10 emotionally detached criminal psychopaths and 10
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healthy control subjects to study fear conditioning. The study used photographs of neutral faces as the conditioned stimulus and would occasionally pair the pictures with a painful pressure, the unconditioned stimulus, in order to test for fear conditioning. In order to look at the circuitry in the brain, MRI scans were taken while the participants were presented with the neutral faces and the occasional shock. The results of the study showed that when compared to the healthy controls, the psychopaths had significantly less activation in the left amygdala and had constant activation in the right amygdala. The experimenters proposed that this difference in activation between the left and right amygdala could be due to differences in stimulus processing, which could also explain why the psychopaths did not show an emotional response to the painful pressure stimulus when compared to the controls. However, even though the psychopaths did not show an emotional response to the painful pressure, they did learn which pictures were associated with the unconditioned stimulus. This shows that the psychopaths did learn the association, they are just unable to process the emotional significance of the association (Birbaumer et al., 2005).

Another study found similar results in regard to fear conditioning in psychopaths. A study by Shultz et al. (2016) had a very similar procedure to the Birbaumer et al. (2005) study except they used a shock as their unconditioned stimulus and it was always associated with specific pictures. When the participants were presented with the pictures they rated on a scale from 0-100 for whether or not they thought they were going to get shocked. The results showed that all the participants learned when to expect to shock. The results also showed that there was significant differential activity in the left amygdala in psychopaths when compared to the controls and that there was also significant differential activity in other areas of the brain that corresponded to the


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fear network (Schultz et al., 2016). These results indicate that there are several differences present between the presence of fear in psychopaths and normal individuals.

In conclusion, the research shows how important the amygdala is for processing these emotions and how abnormalities can alter these emotions to cause abnormal behavior. One interesting finding was that there were a lot of studies that found abnormalities related to the left amygdala but not as many for the right amygdala. This could potentially mean that there is a stronger correlation between the left amygdala and the behaviors expressed by criminals and that lateralization in the amygdala plays a role in criminal behavior. It was also seen that there is a potential that the amygdala could play a role in the etiology of schizophrenia. This could be true however, since other research has shown that amygdala abnormalities have similar implications in individuals that have no history of schizophrenia it could be that the amygdala causes those symptoms in schizophrenia and that it is part of that puzzle, or that the behavior in schizophrenia is caused by something completely different.

The most interesting thing that I think was found in the studies was that violent individuals are sometimes violent because they have increased amygdala reactivity to certain things that can cause an aggressive and violent reaction because they are perceiving it as a threat. Other researchers should look and see if these individuals who exhibit increased amygdala reactivity also have high levels of anxiety because it seems like there could be a correlation. It was also seen that criminal behavior could be caused by the fact that some individuals do not process fear. The studies showed that individuals with psychopathy would be able to learn fearful associations but are not able to process those fearful emotions. This would explain why a lot of criminals know when they are causing someone else pain and suffering, but they continue to do those things to people because they themselves cannot process the emotion of fear and
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therefore do not understand it. Clearly the amygdala has a lot of implications on criminal behavior and once again, it is important that these studies were able to locate these abnormalities and associations because it can help potentially prevent individuals from committing those aggressive acts and also causing pain and suffering on other people.

**Lateralization**

Brain lateralization is important for a lot of functions in the brain. For example, almost every single study presents in this literature review controlled for a confounding variable of handedness by using only right-handed or left-handed participants, since lateralization controls for handedness. It's been seen that there are specific brain areas that control certain functions, however, sometimes there is a specific side of that area that controls the function more. This can be seen when individuals have connectivity problems or have abnormalities when only one side of a brain area is affected. White matter tract abnormalities will also be explored in this literature review in relation to criminal behavior since we know that different brain areas have to function together in order for some processes to function correctly. Lateralization can also be a potentially cause of APD which will be explored more in this review. Abnormalities with connectivity and lateralization potentially cause significant deficits in the brain that cause individuals to participant in criminal actions.

One study took 14 right-handed participants and had them participate in a task where they were presented with a stream of letters and asked to press a button whenever they were presented with a certain target letter (Garavan, Ross, & Stein, 1999). They were told that the target letters would alternate and they would have a different response depending on the letters that were presented and followed. For example, if the target letters were X and Y, when the participants saw the letter X they were told to press the button if the next target letter they saw was Y.
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However, if the next target letter was X then they were instructed to not press the button. This was to measure inhibitory control. The participants underwent fMRI scanning while participating in the experiment and the fMRI results showed that during the response inhibition task there was more activation on the right side of the brain, mainly in the frontal and parietal regions. This shows that response inhibition is potentially lateralized to the right side of the brain so if this area is damaged, then these individuals do not have the proper neural mechanisms to stop certain actions, potentially criminal actions (Garavan et al., 1999).

Another study looked at the lateralization of the ventromedial PFC and the functions of social conduct, decision making, and emotional processing. The participants in this study had to have focal, stable, and unilateral lesions in the right or left ventromedial PFC in order to participate, otherwise they were healthy controls. Social conduct, functioning, and interpersonal relationships were measured using structured clinician based rating scales and family ratings of their personality before and after the lesion occurred. Decision making was measured using a computerized version of the Iowa Gambling Task where the participants were shown four decks of cards labeled A, B, C, and D and the goal of the task was to win as much money as possible (Tranel, Bechara, & Denburg, 2002). The subjects were instructed to pick a card from one of the decks and after they selected a card the computer told them whether they won or lost money. Two of the decks of cards were disadvantageous and would allow the participants to gain money in the beginning of the task but eventually they would have a higher loss. The other two decks were beneficial because they had a higher yield in the long run. It was up to the participants to figure out which decks were going to be more beneficial. Emotional processing and personality were measured by the participants taking multiple scales that measured changes in emotional functioning and personality before and after the lesions. In all three areas it was seen that the
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individuals with the right ventromedial PFC lesions had more severe changes and deficits than the individuals with the left ventromedial PFC lesions. This provides evidence that the ventromedial PFC is lateralized to the right side for functions of social conduct, decision making, and emotional processing (Tranel et al., 2002).

This conclusion is also supported by another study that found strong evidence the decision making is lateralized to the right side of the brain (Manes et al., 2002). This study took five patients who had OFC lesions, four that were on the left side and one that was on the right side. The patients all completed the Iowa Gambling Task explained earlier and it was seen that the patients who had the left OFC lesions performed very similarly to the control subjects that took part in the study. Whereas the patient who had a lesion in the right OFC showed significant deficits in decision making during the task (Manes et al., 2002). Based on these two studies, one can make the conclusion that these higher cognitive processes are lateralized to the right side of the brain and deficits to the right side of the brain are more detrimental than damage to the left side of the brain.

There is also evidence for abnormal connectivity in different brain regions to be associated with criminal behavior. A study by Hoppenbrouwers et al. (2014) used TMS and EEG recordings to study the functional interhemispheric connectivity in 18 psychopathic criminals compared to 15 healthy control participants. The results showed that there was a significant increase in interhemispheric signal propagation from right to left in psychopathic offenders but not in the control subjects. The psychopathic offenders also showed an increase in the intracortical inhibition in the right hemisphere, mainly in the motor cortex. The authors of the study theorize that the left hemisphere in psychopathic criminals has an abnormality that renders it unable to effectively process information from the right hemisphere. This also provides
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evidence that the connectivity between prefrontal regions may be involved in approach versus
withdrawal behavior, which is typically compromised in psychopaths, and could be an
explanation for their antisocial behavior (Hoppenbrouwers et al., 2014).

Other studies have also found evidence that abnormal connectivity could play a role in
APD. Sundram et al. (2012) looked at the connectivity of the white matter tracts in the whole
brain of individuals with APD and diagnosed psychopathy to see if there were any significant
differences compared to the controls. MRI scans were taken of the brains of 15 right-handed
males with APD and 15 right-handed controls. Analysis of the MRI scans showed that the APD
group had significantly reduced white matter connectivity in three different areas: bilaterally in
the genu of the corpus callosum, anterior regions of the white matter in the right hemisphere, and
in the left hemisphere of the anterior and posterior regions of the brain. The reduced white matter
was also seen in the uncinate and inferior fronto-occipital fasciculus (Sundram et al., 2012).

Since most of the areas that were found to have abnormalities were in the white tracts of
different frontal areas, it is reasonable to assume that the deficits that are present in the behavior
of individuals with APD come from these abnormalities. The findings also suggest that people
with APD have white microstructural abnormalities involving frontal white networks and
particularly in the right hemisphere. This is supported since the connectivity was reduced in the
right uncinate fasciculus (UF) in 9 out of the 15 psychopaths (Sundram et al., 2012).

One study looked at the differences in the corpus callosum in individuals with APD. In
order to determine the functional level of the corpus callosum, the participants took part in a
consonant-vowel-consonant identification task and a letter matching task that would show
connectivity patterns in the brain. The results showed that the psychopathic antisocial group had
a 22.6% volume increase in the corpus callosum, a 6.9% increase in length, and 15.3% thinner.
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The authors say that since there were so many differences this could potentially mean that psychopathic APD could be neurodevelopmental because there are other neurological disorders that are also associated with increased corpus callosum volume lie schizophrenia and schizotypal personality disorder (Raine et al., 2012).

Like the corpus callosum, the UF is also a white matter tract that tends to have abnormalities in psychopathic criminals. One study used an imaging technique called in vivo diffusion tensor magnetic resonance imaging (DT-MRI) tractography to analyze the micro integrity of the UF in psychopathic criminals and control subjects. The UF links structures like the amygdala and the OFC together and can play a large role in initiating psychopathic and criminal behavior when there are abnormalities. The results showed that there was significantly reduced connectivity in the right UF of the psychopathic criminals. It was also seen that there was a negative correlation between the factor 2 scores and streamlines in the right and left UF. These findings also suggest that the abnormal connectivity in the amygdala-OFC network, due to the UF, may contribute to the neurobiological mechanisms underpinning the impulsive, antisocial behavior, and emotional detachment associated with psychopathy, criminal behavior, or antisocial behavior (Craig et al., 2009).

Another factor of lateralization that is often explored in criminals is the degree of handedness. One study took 313 participants to examine the relationship between handedness and lateralization of facial processing using the chimeric face test. The chimeric face test takes a vertically split face that is formed with one half of the face showing a neutral expression and the other half showing a positive emotion. The participants view the face twice, once with the emotional side in the left visual field and once with it in the right visual field. The participants reported which face they thought was happier by pressing a button. The participants also filled
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out a handedness questionnaire to determine if they were right or left handed. The results showed that there was a positive relationship between handedness and cerebral lateralization in men but not in women (Bourne, 2008). Another study by Bourne (2005) also tested for lateralization and handedness and they found that even know males and females tend to be right hemisphere dominant, males were found to have a stronger degree of lateralization. One explanation for this is that females have been found to be better at facial recognition than males because there is more bilateral distribution in their facial processing mechanism and that they have more interhemispheric connectivity and transfer than males (Lewin & Herlitz, 2002).

In regard to handedness in criminals, Bogaert (2001) took a group of 2498 white males with criminal history and looked at whether or not there was a correlation between handedness and pedophilia. To test for handedness, the participants choose between the answers ‘right-handed’, ‘left-handed’, ‘ambidextrous’, and ‘right-handed retrained from left-handed’ in response to the question ‘are you right-handed or left-handed?’. The results showed the criminals as 85.8% right handed while the controls were 88.5% right handed and the pedophiles were 84.3% right-handed. While the small 3% or 4% change may not seem to be significant, the author explains that even a 5% difference would be significant and actually look more like a 30% difference in non-right-handedness (Bogaert, 2001).

A study by Fazio, Lykins, & Cantor (2014) also looked at the rate of atypical handedness in pedophiles. The sample used consisted of 1857 men and only 15.7% of them had no history of sexual charges against them. In order to test for handedness, the participants all took a modified version of the Edinburgh Handedness Inventory. To test for the erotic interest in children the penile responsiveness of the participants was tested by using stimuli depicting a variety of activities and persons of erotic interest, full body nude photographs of seven different categories:
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female prepubescent children, female pubescent children, female adults, male prepubescent children, male pubescent children, male adults, or erotically neutral activities. While the participants were looking at the photos, they were being tested on how long it took their penis to become erect and how long it took the erection to end. It was reported here that pedophiles had higher rates of non-right handedness and also had the highest rate of left-handedness, 14.6%, out of the other groups that were tested. Since handedness is lateralized to the brain, right-handedness is lateralized to the left hemisphere and vice versa, this could indicate that individuals who have a high degree of lateralization on the right side of their brain are more likely to be sexual criminals based on the research presented (Fazio et al., 2014). Since it was also seen that atypical handedness is correlated with criminal behavior, it could potentially be assumed that increased connectivity could also cause some abnormal behavior in criminals.

In conclusion, some parts of the brain are specifically lateralized for certain functions, like handedness. Research showed that criminal pedophiles had an increased rate of non-right-handedness which is potentially reflective of lateralization abnormalities in their brains. It also seems like there is a lot of lateralization in the ventromedial PFC since the Tranel et al. (2012) study found such severe social and cognitive deficits associated with lesions to the right ventromedial PFC. This finding helps support the theory that psychopaths cannot process information from the right hemisphere and shows how the right hemisphere is lateralized for more important functions that we are not totally aware of. However, the research also showed that even though lateralization is important for some of these functions, abnormal connectivity can also produce significant deficits in individuals. For example, some of the research showed that individuals with APD have significantly reduced white matter tracts and other research showed that they have an increase in corpus callosum volume. All the research combined shows
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support for lateralization differences being a cause of abnormal behavior, however, there are so many things associated with lateralization and connectivity that it would be impossible to narrow down a singular cause of criminal behavior based on these findings.

Discussion

This literature review compared the PFC, amygdala, and brain lateralization in the brains of criminals and normal healthy individuals to try and determine a cause for their criminal behavior. The research has shown that deficits to all three of these areas have significant detrimental impacts on the behavior of these individuals. Deficits to the PFC caused individuals to exhibit severe emotional deficits and cognitive processing. If the PFC is damaged at an early age, then lots of normal social functions and cognitive processes like being able to empathize with people and decision making are compromised. We saw a high correlation with this in the studies where decreased PFC GMV and significant cortical thinning were present and the individuals had significant emotional deficits. However, this may not be the complete fault of structural abnormalities in the PFC. As seen later in the review, other studies talked about the lateralization issue in the ventromedial PFC and how deficits to just the right side and not the left caused severe social, cognitive, and emotional deficits in these individuals. This potentially shows that while there are structural differences that can cause abnormalities in criminal minds, sometimes it is also connectivity or lateralization that can cause issues.

Some of the studies related to APD talked about how deficits to both the PFC and the amygdala could be a predictor for this disorder. Since APD and antisocial behaviors in general are sometimes present in criminals, it is important to talk about how the two potentially play a role in the development of APD. The studies took offenders that had been diagnosed with APD and test them for both PFC and amygdala abnormalities. It was concluded by a few studies that
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individuals who have APD had extreme deficits to the PFC such as lack of empathy and lack of regret. However, some other defining features of APD like fearlessness were found to be caused by abnormalities in the amygdala. This shows how one brain area cannot necessarily be responsible for all the abnormal behaviors that make up a neurological disorder and that there could always be a confounding variable that isn’t being accounted for. For example, it was also reported in the lateralization section of this review that the corpus callosum has increased volume in some individuals with APD while others present white matter reductions. This also shows us that different types of deficits can produce the same kind of behavior which can make finding neurological markers for identifying people who may be at risk for becoming criminals very difficult.

Criminal behavior was also found to be associated with white matter tract differences in the brain. It was seen that there were several abnormalities with the connectivity, especially in psychopaths. The theory that psychopaths cannot necessarily process information from the right hemisphere helps strengthen the argument for lateralization differences associated with criminal behavior, and that deficits to the right ventromedial PFC, along with other right brain areas mentioned in this review, because there were more deficits to the right side of the brain than the left. This does again prove however, that it is increasingly difficult to identify a specific predictor or causation for criminal behavior because the behaviors associated with this deficit have also been seen with other brain areas as well.

The take home message from this literature review is that there is not necessarily one single causation factor for criminal behavior. First of all, different criminals commit very different types of acts. One criminal might just steal something while another criminal might kill someone. While we have found associations with criminal behaviors for specific brain areas,
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most of these behaviors could actually be controlled by more than one area, or even through the connectivity of several brain areas. Instead of identifying neurological deficits as risk factors for potentially criminal behavior, it would be more beneficial to identify behavioral risk factors as the front line of defense and then try to figure out which brain areas are causing these deficits and see if there is a treatment developed to try and fix the problem. Future research should focus on trying to find treatments for fixing these criminal behaviors in order to not only lower the rate of individuals committing violent criminal acts the first time, but also to prevent criminals from recriminating crimes when they get released from jail. Also developing treatments to cure individuals from these behavioral tendencies could increase the likelihood of criminals being cured and eventually being released from jail verses serving a life sentence.
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References


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