

# Neural structures: subserving psychological function



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This essay will evaluate what is known about the role of neural structures in subserving emotion. It was concluded that although emotion is a difficult behaviour to study scientifically, clear importance of the role of the amygdala has been found. Nonetheless, other structures and brain regions are involved in the responses to emotion, and how they interact together is an area in need of further investigation.

Neural networks have been defined by Colman (2009) as a system of interconnected neurons. These systems can be either in the nervous system or in the brain. This essay will focus on the role of these neural structures in emotion. Colman (2009) defined emotion as a short-term evaluative, affective and intentional psychological state. The cognitive neuroscience of emotion has been slow to become widely recognised, as emotion is a behaviour that is difficult to study in a systematic manner. Recently however researchers have been challenging this gap in knowledge, and as a result, emotion is quickly emerging as a critical research topic (Gazzaniga, Ivry & Mangun, 2009).

## BASIC HUMAN EMOTIONS

Ekman and Friesen (1971) set out to find the basic human facial representations. From their cross-cultural work they suggested that anger, fear, disgust, happiness, sadness and surprise are the six basic human facial expressions that represent all emotional states. Despite there still being considerable debate about whether a single list is enough to incorporate all emotional experiences, it is generally agreed that these are the basic, universal human emotions (Gazzaniga et al., 2009); these emotions will therefore be the ones focused on later in the essay.

#### HOW RESEARCH HAS DEVELOPED

Early research into the cognitive neuroscience of emotion mainly focused on identifying the limbic system as the emotional brain (MacLean, 1949).

Recently research has been focused on specific types of emotional tasks and identifying the neural systems underlying specific emotional behaviours. It is no longer thought that there is simply one neural circuit of emotion, rather that there are usually a number of different neural systems involved, dependant on the emotional situation (Gazzaniga et al., 2009).

#### THE ROLE OF THE AMYGDALA

The amygdala is a small structure in the medial temporal lobe. This structure has been a focus of research on emotional processing in the brain since Weiskrantz (1956, as cited in Gazzaniga et al., 2009) identified the amygdala as the primary medial temporal lobe structure underlying the fear related deficits in a medical condition known as Klüver-Bucy syndrome.

The amygdala receives inputs from every sensory system and is thought to be the structure where the emotional significance of sensory signals is learned and retained (Pinel, 2008).

Sergerie, Chochol and Armony (2008) carried out a meta-analysis of functional neuroimaging studies looking at the role of the amygdala in emotional processing. Previously many functional neuroimaging studies have given solid support for an important role of the amygdala in negative emotional processing (Sergerie et al., 2008). The rationale behind this study was to address the issue of whether factors such as sex, valence and stimulus type have an effect on the magnitude and lateralization of amygdala reaction. The results confirmed that the amygdala reacts to both positive and negative emotional stimuli, particularly when participants were exposed to faces showing emotional expressions (Sergerie et al., 2008). Differences were not found in amygdala lateralization as a function of sex or valence. Strong support was also shown for a functional dissociation between the left and right amygdala in terms of temporal dynamics. The findings of this study indicate that the amygdala is involved in the processing of positive emotion as well as negative emotion.

Following the large amount of empirical evidence showing the role of the amygdala in emotional processing, LeDoux (1996) warned that it may be tempting to conclude that the amygdala is at the centre of emotion reaction in the brain. This would be erroneous however, as there are clearly other structures involved in emotional processing. For the role of the neural system in emotion to be fully understood, further research is needed into the other structures involved.

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## THE ROLE OF THE MEDIAL FRONTAL LOBES

Recently, functional brain imaging studies have shown evidence of activity within the medial frontal lobes whilst emotions are being both cognitively suppressed or re-evaluated (Quirk & Beer, 2006). The latest studies of medial prefrontal lobe activity have used suppression paradigms (where participants are told to suppress their emotional reactions to unpleasant images) or reappraisal paradigms (where participants are asked to try to reinterpret an image to adjust their emotional reaction to it) (Quirk & Beer, 2006). The medial frontal lobes have been found to be active when both of these paradigms have been studied, and it seems that they interact with the amygdala to exert their cognitive control of emotion (Holland and Gallagher, 2004).

These studies show that the medial frontal lobes have a role in the processing of emotion; further investigation is required in this area to reveal exactly what role this structure plays and how it interacts with other structures in the brain.

## THE REGULATION OF EMOTION

Mak, Hu, Zhang, Xiao and Lee (2009) investigated the regulation of emotion through functional magnetic resonance imaging. The study identified neural correlates of the regulation of positive or negative emotion. The study of the regulation of emotion is important, as dysregulation of emotion is associated with the inability to modulate intense emotions that may worsen affective disorders (Mak et al., 2009). Whilst either viewing emotional pictures or regulating their emotions induced by these pictures, participants brain  
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activities were monitored (Mak et al., 2009). The neuroimaging findings showed that the left superior and lateral frontal regions were common neural correlates of regulation for both emotions. The prefrontal regions and the left insula were found to be associated with regulation of positive emotion, while activity in the left orbitofrontal gyrus, the left superior frontal gyrus and the anterior cingulate gyrus appear to be associated with regulation of negative emotion. In conclusion, Mak et al. (2009) suggested that there are both shared and specific neuro-cognitive mechanisms involved in the regulation of positive and negative emotions.

If knowledge was to be enhanced into the neural mechanism behind emotion regulation, the understanding of the complex interaction between emotion and basic human behaviours could be improved. Through understanding the neural mechanisms behind emotion regulation, helpful insights could be provided into the biological basis of mental health (Mak et al., 2009).

## THE ROLE OF INDIVIDUAL DIFFERENCES

Several studies into the neural mechanisms of emotion have focused on individual differences. One of these studies, by Adolphs et al. (1999) tested how well nine neuropsychological patients with bilateral amygdala damage could identify emotion in facial expressions. As previously reported, the group as a whole was found to have problems identifying the emotion of fear (Adolphs et al., 1999). There were however, individual differences amongst the patients; some had difficulty identifying other negative emotions whereas two of the patients had no problem identifying emotions in facial expressions at all. Adolphs et al. (1999) said that remarkably these latter

two patients had total bilateral amygdala lesions as revealed by structural MRI's.

Canli, Sivers, Whitfield, Gotlib and Gabrieli (2002) used functional MRIs to look at the differences between the reactions of healthy participants who scored high in extraversion (who tend to have positive emotional reactions) and those who scored high on neuroticism (who have a tendency towards negative emotional reactions). It was found that all of the participants showed increased activity within the amygdala when viewing images of fearful faces, however only extraverts showed increased amygdala activity from viewing images of happy faces (Canli et al., 2002).

These two studies indicate that individual differences affect the roles of neural structures in relation to emotion (Adolphs et al., 1999; Canli et al., 2002). This suggests that neural structures may play varying roles in experiencing emotion depending on the person, meaning that research into the roles of neural structures needs to consider differences between individuals for their findings to be relevant. A case study into one individual may show certain roles of a neural structure in emotional processing, however in another person this role may be slightly different.

## **NEURAL NETWORK MODELLING OF SPECIFIC EMOTIONS**

Previously, the majority of the research into the neural network modelling of emotion has differentiated positive versus negative affect. Recently however, neural network modelling of specific emotions is beginning to emerge (Levine, 2006). The emotions mainly focused on in this research are

the ones that were distinguished by Ekman and Friesen (1971), as mentioned earlier.

## THE NEURAL BASIS OF ANGER

Blair, Morris, Frith, Perrett and Dolan (1999) carried out a study into the neural basis of anger. To do this they exposed subjects to either neutral or increasingly angry facial expressions while analyzing the areas of brain activation associated with the gradient of the intensity of anger. Blair et al. (1999) found the right orbitofrontal cortex became increasingly active when subjects were exposed to increasingly angry faces. These results suggest that the orbitofrontal cortex plays a role in explicit emotional labelling of angry faces.

The role of the orbitofrontal cortex was further demonstrated by Sander et al. (2005). Participants were presented with meaningless phrases spoken with neutral prosody in one ear, and with angry prosody in the other. Participants were told to either attend to one ear or the other. It was found that activity in the right amygdala and superior temporal sulcus was changed independent of attention. Alternatively, the orbitofrontal cortex was only activated when the angry prosody had been attended to. This finding implies further that the orbitofrontal cortex is important for the explicit processing of anger. What now should be investigated is whether, and to what extent, individual differences have an effect; this could potentially help people who have problems with their anger by identifying the differences so that a solution can be found.

## THE NEURAL BASIS OF SADNESS

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Using the same paradigm, Blair et al. (1999) also investigated the neural basis of sadness. They found both the left amygdala and the right temporal lobe demonstrated activity linked with the intensity of sad expressions. These findings have however been contradicted by other recent studies. Adolphs and Tranel (2004) used a more sensitive approach, which involved the participants rating the intensity of an emotion rather than labelling it. They found that damage in the right amygdala caused a greater deficit in identifying sad faces when compared to damage to the left amygdala. Adolphs and Tranel (2004) believed that this difference in conclusions may have been due to the more insightful approach.

There has not been much agreement for the neural basis of sadness, therefore this is an area of emotion which requires further research so that the roles of neural structures can be clarified.

## THE NEURAL BASIS OF FEAR

Fear conditioning has become the preferred method of investigating fear as the source of fear is unambiguous and the development of the fear response can be systematically investigated (Pinel, 2008).

Romanski and LeDoux (1992) studied the neural mechanisms of auditory fear conditioning by creating lesions in the auditory pathways of rats. It was found that bilateral lesions of the medial geniculate nucleus blocked fear conditioning to a tone; bilateral lesions of the auditory cortex however did not. The findings suggest that signals created by the tone only have to be able to reach the medial geniculate nucleus, not the auditory cortex, for auditory fear conditioning to occur. This also indicates that a pathway plays

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a crucial role in fear conditioning, going from the medial geniculate cortex to a structure other than the auditory cortex; this structure was proved to be the amygdala (Romanski & LeDoux, 1992). They then found that lesions in the amygdala also blocked fear conditioning.

Romanski and LeDoux (1992) argued that just because auditory cortex lesions do not disrupt fear conditioning does not mean that this structure is not involved in auditory fear conditioning. This is because there are two pathways from the medial geniculate nucleus to the amygdala. These are the auditory thalamus, and the auditory cortex; the indirect one, capable of mediating fear conditioning to more complex sounds (Jarrell et al., 1987, as cited in Pinel, 2008).

Similarly, Armony et al. (1997) proposed a brain-based neural network model of auditory fear conditioning. Included are parallel cortical and subcortical pathways, reaching the primary emotional processing areas of the amygdala, as also shown by LeDoux (1996). It has been found that the subcortical pathway is quicker than the cortical, however the cortex performs more precise discrimination than the thalamus pathway. This finding suggests that the two pathways are involved in performing complementary functions; the subcortical pathway is vital in the presence of potentially dangerous stimuli where a fast response is crucial, and the cortical pathway is more useful where more detailed evaluations of stimuli are needed (Armony et al., 1997).

Studies into fear have continually identified the amygdala as the main brain structure involved in the acquisition, storage and expression of conditioned

fear (Armony et al., 1995; 1997, Romanski & LeDoux, 1992), therefore the role of the amygdala in fear conditioning is a widely accepted and stable notion.

#### THE NEURAL BASIS OF SURPRISE

Not many studies have investigated the emotion of surprise, however it is believed that surprise has important survival value, and therefore must be accessed early in the course of sensory processing (Plutchik & Kellerman, 1986). To enable this, direct inputs to the amygdala from primary pathways provide this access, modulated by the swift habituation of sensory evoked responses in the amygdala. Because of this rapid action, surprise tends to be a short lived emotion, which leads on to another emotional state (Plutchik & Kellerman, 1986); potentially making surprise a difficult emotion to study.

#### THE NEURAL BASIS OF DISGUST

Generally throughout the study of the neural basis of disgust, there has been a broad consensus that at least one area, the anterior insula, is crucial for both the detection and feeling of disgust (Philips et al., 1998). Based on imaging studies, this conclusion is in line with a study on a patient with insula damage whom is incapable of detecting disgust within varying modalities (Calder, Keane, Manes, Antoun, & Young, 2000).

Wicker, Keysers, Plailly, Royet, Gallese and Rizzolatti (2003) supported these findings, and went even further by analysing neural responses while watching others experience disgust, and firsthand experience of disgust. It was observed that in both these conditions the same part of the anterior

insula was activated. These findings suggest that maybe understanding the emotions of others could require stimulation, and mildly experiencing, the emotions ourselves. This also implies a potential role of emotion in empathy (Gazzaniga et al., 2009).

These findings by Philips et al. (1998), Calder et al. (2000) and Wicker et al. (2003) provide evidence that the insula is a neural correlate of experiencing disgust directly. The study by Wicker et al. (2003) also shows that the insula is essential in identification of disgust in others. Therefore, this indicates that the insula plays a role in the emotion of disgust, however the importance of this role is unknown.

#### NEURAL CORRELATES OF HAPPINESS, SADNESS AND DISGUST

An investigation into the neuroanatomical correlates of happiness, sadness and disgust was carried out by Lane, Reiman, Ahern, Schwartz and Davidson (1997). They used positron emission tomography to measure regional brain activity during exposure to happiness, sadness and disgust induced by film and recall. They found that happiness, sadness and disgust were all linked with increased activity in the thalamus and the medial frontal cortex, and also activation of anterior and posterior temporal structures, mainly when the emotions were induced by film. When sadness was recalled this linked with increased activation in the anterior insula; happiness was distinguished from sadness through greater activity around the ventral mesial frontal cortex. Lane et al. (1997) concluded that there seem to be a number of regions in the brain that are involved in emotions, with different combinations of structures concerned in feeling and identifying different

emotions. This finding backs up LeDoux's (1996) reluctance to conclude that the amygdala is the centre of emotional reaction.

## EVALUATION OF METHODS

Positron emission tomography (PET) is a technique often used in studies investigating co-morbidity. It provides images of brain activity, however these images are not of the brain, they are merely coloured maps giving an indication of the amount of radioactivity in the brain (Pinel, 2008). This means that it can only be estimated how much activity there is in each particular part of the brain, and therefore it is not a particularly accurate method of measuring brain activity in specific regions (Pinel, 2008).

Another commonly used method of investigating brain activity in cognitive neuroscience is functional MRI (fMRI). The main strength of fMRI is that it provides both structural and functional information about the brain in one image (Posner & Raichel, 1997), therefore revealing the brain function. This gives it an advantage over PET as a more precise image is produced (Pinel, 2008). Other advantages of this method over PET are that it provides a better spatial resolution, and three-dimensional images can be produced showing activity in the entire brain (Pinel, 2008).

This information suggests that studies into the role of neural structures in emotion may be more reliable if the evidence comes from fMRI measurements, as a more accurate indication of which brain regions are activated at a certain time is given.

## CONCLUSION

Through examining the literature surrounding the role of neural structures in emotion, it can be concluded that neural structures do play an important role. However, the significance of the role of neural structures in comparison to other factors, such as individual differences is still not clear. It has been proposed that neural structures have differing functions in the experience of emotion depending on the individual (Adolphs et al., 1999; Canli et al., 2002). This suggests that further research is needed in the field of individual differences to find these underlying factors, so that the function of neural structures can be more fully understood.

Many challenges are faced in the study of emotion, as it is a behaviour that is difficult to define, manipulate and study with a scientific approach (Gazzaniga et al., 2009). Even so, investigation into the cognitive neuroscience of emotion has generally emphasized the importance of the role of the amygdala. The function of this structure in the response of emotion has been greatly influenced by research into animals; in both humans and other species the fact that the amygdala plays a vital role in the fear response has been demonstrated (Gazzaniga et al., 2009).

The role of the amygdala is not the only structure researched in trying to identify the neural correlates involved in emotion, as recently different emotions have successfully been associated with other neural structures, including the orbitofrontal cortex in anger (Blair et al., 1999), and the insula, involved in disgust (Wicker et al., 2003).

Nevertheless, an emerging change in the way the cognitive neuroscience of emotion is moving the emphasis from the study of individual neural structures to the investigation of neural systems (Gazzaniga et al., 2009). It is clear that the amygdala, orbitofrontal cortex and insula are vital in the processing of emotion. It is now important that in order to enable how the brain produces both normal and adaptive emotional responses to be understood, the way that these structures interact together (with each other and with other brain regions) and the effect of individual differences needs to be investigated.

## **FURTHER READING**

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2009). (See References). Gives a general overview of the neural networks involved in emotion, particularly the amygdala.

Plutchik, R. & Kellerman, H. (1986). (See References). Gives more in depth detail of the networks involved in specific emotions.

Sergerie, K., Chochol, C., & Armony, J. L. (2008). (See References). Looks at previous research into the role of the amygdala in emotional processing which gives new information regarding previously proposed models.