The neurobiological basis of hyper-religiosity

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Abstract

The neurobiological basis of hyper-religiosity is discussed by comparing the neurobiological substrates of the four disorders in which hyper-religiosity usually occurs. These disorders are obsessive-compulsive disorder (OCD), schizophrenia, temporal lobe epilepsy (TLE), and mania. After an introduction on hyper-religiosity, the four disorders and their neurobiological basis are discussed in four separate chapters. An integrating chapter compares all brain areas involved in the four disorders and through this comparison, a general neurobiological basis of hyper-religiosity is found. The main areas involved in hyper-religiosity are the frontal lobes, the temporal lobes, and the limbic system. In the discussion, the limitations and validity of the thesis are discussed, and hyper-religiosity is compared to the regular expression of religiosity.

Keywords: Hyper-religiosity, obsessive-compulsive disorder, schizophrenia, temporal lobe epilepsy, mania.

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1. Introduction

Religion exists in many shapes and forms. In Western society, Christianity is the most practiced form of religion. In the Middle-East, Islamic beliefs are most common. There are similarities but also differences within and between all forms of religion. This paper does not aim to cover one form of religion, but religion in general from which the definition of hyper-religiosity will be formed. In this way, hyper-religiosity will not be used in the context of one religion, but in the context of religion in general. The definition of religion used here is beliefs about the existence of supernatural entities. Within these beliefs, these entities are able to influence the natural world and are gatekeepers to life after death (Boyer, 2001).

The question of why people believe in supernatural entities and eternal life after death has not been answered satisfactorily although there are theories about this. Vail, Rothschild, Weise, Solomon, Pyszczynski, and Greenberg (2010) argue that people become religious and spread their religion because of their existential fear, their fear of the inevitability of death. Others, for example Boyer (2001), consider religion as a nonadaptive byproduct of other human qualities that have evolved by natural selection. Another view is provided by Ysseldyk, Matheson, and Anisman (2010), who believe that eternal group membership by which people can identify themselves is an important motivation for religion. Sedikides and Gebauer (2010) add self-enhancement to this list of theories, which they defined as socially desirable responding.

Religion influences individuals and the society in which they live. This influence can be either positive or negative. The strong group membership which is facilitated by religiosity can cause an individual to have a good social support system. But at the same time conflicts can arise between different groups, which can happen in the form of wars between countries or civil wars.

Hyper-religiosity is an excessive or extreme form of religiosity. In this paper, hyper-religiosity is considered a psychopathological form of extreme religiosity, which is mainly found in patients with a psychological or psychiatric disorder. The symptoms vary greatly among patients, with some patients experiencing only one of the symptoms while others experience a multitude of symptoms. The symptoms can also vary in degree of severity. Some symptoms of hyper-religiosity are visual and/or auditory hallucinations of God or other religious figures, feelings of being one with the world around you and/or God, intense emotions of God's presence, and the conviction that you are chosen by God or another religious figure to carry out a certain task. What is striking about these symptoms is that the focus is not on central aspects of religion, like taking care of others, but on very specific, exaggerated tasks, emotions or perceptions.

There are no reported cases of individuals without a psychiatric or neurological disorder that suffer from hyper-religiosity. The question therefore remains if hyper-religiosity is an extreme form of normal religiosity or if it should be considered as an expression of psychopathology that has nothing to do with the regular expressions of religion. This paper does not aim to answer this question, although some links will be made between the neurobiological basis of hyper-religiosity and regular religiosity in the discussion.

Even though some people consider religion and hyper-religiosity as supernatural and thus unapproachable by science, the approach of this paper is that these phenomena can at least partly be explained by the activity or size of certain neural structures. This link between hyper-religiosity and the brain will be made by studying four different psychiatric and neurological disorders in which hyper-religiosity has been reported. These disorders are obsessive-compulsive disorder, schizophrenia, temporal lobe epilepsy, and mania. These disorders will be discussed in four different chapters, after which there will be a fifth chapter in which a comparison will be made between the neural structures that are involved in these

disorders as to uncover the neurobiological basis for hyper-religiosity. The goal of this paper is giving an overview of the neurobiological basis of hyper-religiosity.

2. Obsessive-compulsive disorder and hyper-religiosity

Obsessive-compulsive disorder (OCD) is an anxiety disorder. It is characterized by obsessions, which are thoughts or images that the person is severely preoccupied with, and compulsions, which are mental or behavioural repetitive tasks that a person feels enforced to do. OCD is classified as an anxiety disorder because the obsessions cause great anxiety in the person and the compulsions serve as a way to reduce or prevent this anxiety (Comer, 2011a).

In the text revision of the fourth edition of the Diagnostic and Statistical Manual for Mental Disorders of the American Psychiatric Association (*DSM-IV-TR*, 2000), the main diagnostic criteria for OCD are having obsessions and/or compulsions and an awareness of the excessiveness or unreasonable nature of the obsessions or compulsions. Furthermore, the *DSM-IV-TR* (2000) states that the obsessions or compulsions must cause suffering or take at least one hour every day, and are not caused by physiological effects of drugs or disease.

The prevalence of OCD is estimated around 1-2% of the world population at a given time (Comer, 2011a). According to Angst et al. (2004), 3.5% of the population develop OCD in their lifetime. Comer (2011a) also states that the prevalence is the same in men and women and in different ethnic and cultural groups. This would mean that OCD is equally common among different religious groups as well.

Through factor analysis, many authors have tried to cluster the many symptoms of OCD in distinct categories. The Yale-Brown Obsessive-Compulsive Scale (Y-BOCS) assesses the main symptoms that the patient suffers from and the severity of these symptoms. This questionnaire was used in these studies to cluster the symptoms into separate dimensions. Denys, De Geus, Van Megen, and Westenberg (2004) have made an overview of these studies and also conducted a factor analysis on the items of the B-YOCS themselves. The results of all these studies are mixed, but more often than not was a religious dimension present, whether or not in combination with sexual and/or aggressive symptoms. These findings suggest that religious obsession in OCD is a valid subcategory of the disorder and should be treated as such.

Other than the dimension of religious obsessions in OCD that has been found in factor analysis studies with the B-YOCS, religion is also mentioned in relationship to OCD in a slightly different way. Scrupulosity is a term that is often used to indicate religious symptoms in OCD, although the relationship between scrupulosity and OCD is unclear (Miller & Hedges, 2008). The *DSM-IV-TR* (2000) does not mention scrupulosity in the classification of OCD, but it does so briefly in the classification of obsessive-compulsive personality disorder (OCPD), indicating an exaggerated sense of morality, ethics or norms. It is unclear whether scrupulosity must be considered a subcategory of OCD or OCPD (like the religious obsession dimension found in factor analysis), or if it is a distinct disorder (Miller & Hedges, 2008). Anyhow, scrupulosity is used in the former way in the literature which is how it will be used here as well.

Scrupulosity is thus defined as religious symptoms that occur in OCD. It is often expressed as unwanted obsessive thoughts about unsacred happenings or deities (e.g. Satan), a fear of sin or a preoccupation with thoughts about whether one has sinned, and extreme religious behaviour (excessive confession or prayer) (Nelson, Abramowitz, Whiteside, & Deacon, 2006). Olatunji, Abramowitz, Williams, Connolly, and Lohr (2007) investigated the two main factors of the Penn Inventory of Scrupulosity and concluded that the two domains of scrupulosity are the Fear of Sin and the Fear of God.

There are no studies that state that hyper-religiosity and scrupulosity are the same disorder, but the similarities are striking. Both patients with hyper-religiosity and scrupulosity have obsessions with religion and show extreme religious behaviour. Additionally, hyper-religiosity and scrupulosity are both severe disabling disorders which may cause social and/or occupational dysfunctioning. Another aspect that scrupulosity and hyper-religiosity have in

common is the abnormal focus on an aspect of religion that is not central to the religion and directs the focus away from the central aspects of the religion (Greenberg & Shefler, 2002). Examples of this are excessive ritualistic prayer, extreme fears of sin to the point where doing good things is out of focus, and fear of God or being punished by God.

In a symptom stability follow-up study done by Mataix-Cols et al. (2002) it was found that the sexual/religious dimension, together with the hoarding dimension, were the most stable symptom clusters found in OCD. These two clusters did not show significant decrease or change in a time-period of two years, while the other clusters did show significant fluctuations in symptoms. This difference between the religious dimension and other dimensions might also point to a link between hyper-religiosity and religious obsessions in OCD. Hyper-religiosity appears to be stable over time, just like the religious symptoms of OCD are, according to this study.

Scrupulosity or religious obsessions and compulsions are not uncommon in patients with OCD, but the actual percentage is unclear. There are some studies which have investigated this with mixed results. For example in the study done by Tek and Ulug (2001), 42% of the OCD patients suffered from religious obsessions. Eisen et al. (1999) found that 10.4% of the OCD patients showed religious obsessions and 3.9% religious compulsions and Tolin, Abramowitz, Kozak, and Foa (2001) showed that 5% of their subjects with OCD exhibited a religious obsession as their primary obsession. Tek and Ulug (2001) also compared studies that were done all over the world on the prevalence of religious obsessions in OCD and the numbers fluctuated between 5 and 60%.

Since scrupulosity in the OCD population is not uncommon and scrupulosity is very similar to hyper-religiosity, the neurobiological information of OCD will be used to find the neurobiological basis of hyper-religiosity. The biological aspects of scrupulosity have not yet been studied, so studies of OCD in general will be used. In the next section, the main brain areas involved in OCD will be discussed.

Brain areas

There has been done a lot of research on the neurobiological basis of OCD. Some researchers have focused on the activity or inactivity of certain brain structures, while others investigated the structural differences in the brain compared to healthy individuals. This section will focus on both kinds of research to try and determine the neurobiological basis of OCD and ultimately hyper-religiosity.

There has been a lot of attention for structural differences in the brain of OCD patients compared with healthy individuals. This structural difference is usually found by comparing the volume of grey matter or white matter in the brain of patient and healthy populations. White matter consists of nerve fibers with myelin sheaths and grey matter consists mostly of capillary blood vessels and cell bodies (Kolb & Whishaw, 2006). So if the amount of white matter is reduced in a structure, there are less strong connections of nerve fibers and if the amount of grey matter is reduced, there are less blood vessels and cell bodies (including synapses) in a structure.

Grey matter abnormalities were investigated in the studies by Szeszko et al. (2004), Kopřivová et al. (2009), and in a meta-analysis of ten recent studies by Rotge et al. (2010). The results of these studies are somewhat inconsistent, since they found both increases and decreases of grey matter throughout the brains of OCD patients compared to healthy individuals. Reduced grey matter was found in the superior frontal gyrus, the supramarginal gyrus, the dorsolateral prefrontal cortex, and the medial frontal gyrus by Rotge et al. (2010). The grey matter reduction in the medial frontal gyrus was also found by Kopřivová et al. (2009). They also found grey matter reduction in the right temporo-parieto-occipital area, the right precentral gyrus, the left middle temporal and the left cerebellar area, bilateral pons and

mesencephalon. The area that Szeszko et al. (2004) found to be smaller was the globus pallidus, especially on the left side. Increased grey matter was found in the anterior cingulate gyrus (especially on the left). Grey matter increase was also found by Rotge et al. (2010) in the putamen and inferior frontal gyrus. Concluding, these studies did not find much overlap of grey matter abnormalities in the brain of OCD patients. The only area which overlaps in the studies is the medial frontal gyrus, which contains less grey matter according to two studies. The differences between the findings of these studies suggests that grey matter abnormalities (both increased and decreased) could be a general occurrence throughout the brain of OCD patients.

Recently, white matter abnormalities have also been under investigation in OCD patients. The results of these studies all found white matter reduction and no white matter increase in OCD patients compared to healthy controls. Kopřivová et al. (2009) found a global white matter reduction in OCD patients. Others found more specific white matter decreases in the patients. There is some overlap between the areas with decreased white matter in the different studies. Decreased white matter in the corpus callosum was found by both Nakamae et al. (in press) and in the review by Fontenelle, Harrison, Yücel, Pujol, Fujiwara, and Pantelis (2009). The area of the cingulate cortex has also been found to have less white matter in different studies. Nakamae et al. (in press) found less white matter in the right cingulum, Szesko et al. (2005) in the anterior cingulate gyrus and in the right posterior cingulate gyrus, and Fontenelle et al. (2009) in the cingulum. A third area of the brain which was implicated in more than one study was the internal capsule. Both Namakae et al. (in press) (in the left anterior limb of the internal capsule) and Fontenelle et al. (2009) (in the internal capsule) found decreased white matter in this area. Areas with a white matter reduction that did not overlap in the different studies were the bilateral supramarginal gyri, and the left lingual gyrus found by Szesko et al. (2005), and the frontal cortex (especially the orbitofrontal cortex), and the parietal lobes found by Fontenelle et al. (2009). In summary, all three overlapping areas of white matter reduction in OCD patients were subcortical areas, but cortical areas were also found to have decreased white matter. It seems that white matter abnormalities are more global than grey matter abnormalities, both in number and in consistency of overlap between the studies.

In the review by Fontenelle et al. (2009), it was emphasized that white matter abnormalities are apparent in OCD and that this finding, combined with the large body of research about grey matter abnormalities, may suggest that OCD is not caused by deviances in separate brain regions, but by the disruption of networks within the brain. This conclusion is supported by functional imaging studies, which measure the activity or inactivity of brain structures.

The results of many functional imaging studies have been summarized in the paper written by Aouizerate et al. (2004). An increased activity in the orbitofrontal cortex was found often, either bilaterally or on one side of the brain during obsessive and/or compulsive symptoms. Increased activity was also found in the bilateral anterior cingulate cortex, the head of the caudate nucleus (bilaterally or right-sided) and the bilateral or right thalamus. In contrast, the dorsolateral prefrontal cortex was shown to have a decreased activity in OCD patients.

In a different paper by Menzies, Chamberlain, Laird, Thelen, Sahakian, and Bullmore (2008), even more functional imaging studies have been compared to unravel the neurobiology of OCD. Menzies et al. (2008), just like Aouizerate et al. (2004), found that the head of the caudate nucleus (left and right) showed increased activity in OCD patients, just as the right anterior and posterior orbitofrontal cortex and the orbital gyrus (bilaterally). The increased activity in the anterior cingulate and the thalamus was also found bilaterally in both the study of Aouizerate et al. (2004) and the study by Menzies et al. (2008). In addition to

these areas, there were a few areas with increased activation that were not mentioned in the paper by Aouizerate et al. (2004), but that were found by Menzies et al. (2008). These were the posterior cingulate, the bilateral parietal cortex and left parieto-occipital cortex, as well as the left inferior parietal cortex and the left amygdala.

Some areas which show a decreased activity compared to healthy individuals have also been identified by Menzies et al. (2008). These areas are the left putamen, the right cerebellum, and curiously the left amygdala and the left anterior cingulate, which were also found to have an increased activity in OCD patients.

Some brain areas or networks have been linked more specifically to certain symptoms of OCD (e.g. hoarding or checking compulsions) (Aouizerate et al., 2004). This has not been done for religious obsessions or compulsions. Therefore, no more information on these areas can be given about their links to scrupulosity.

The discussion of the different models that have been constructed to explain the symptoms of OCD and the brain areas involved is beyond the scope of this paper. Nevertheless, it is worth to note that all these models emphasize the involvement of disrupted connections between the orbitofrontal and cingulate cortex (limbic area) and the basal ganglia, which are connected through the thalamus (Auoizerate et al., 2004). These areas were all found to have increased activity compared to healthy individuals through functional imaging studies. Even though these models propose plausible theories, this mechanism is not the only disruption in the brain involved in OCD, considering that there are also other dysfunctioning brain areas that are not involved in these connections.

In summary, it seems that the frontal cortex and the limbic system are the areas that are most prominently linked to OCD. In some studies, the parietal, temporal and occipital cortex have been mentioned as well, although the link is less clear with these areas.

3. Schizophrenia and hyper-religiosity

Schizophrenia is a psychotic disorder in which people often lose their contact with reality. There are three groups of symptoms that may be present in schizophrenia. These are positive symptoms, negative symptoms, and psychomotor symptoms (Comer, 2011b). Positive symptoms are strange additions to the behaviour of the person. They include delusions, disorganized thinking and speech, hallucinations, and inappropriate affect. Delusions are false ideas that are not based on facts and hallucinations are perceptions without a demonstrable stimulus. Negative symptoms are deficits in the behaviour of the patient. These include poverty of speech, flat affect, and social withdrawal. The final group of symptoms are psychomotor symptoms, which consist of odd gestures or postures.

According to the *DSM-IV-TR* (2000), the diagnosis of schizophrenia can be made when the patient shows two or more positive or negative symptoms and when the level of social and occupational functioning is clearly below the level of functioning before the onset of the disorder. The symptoms must be present for at least six months before the disorder can be diagnosed and the symptoms must not be the result of drug use or other disorders.

The *DSM-IV-TR* (2000) also describes five subtypes of schizophrenia. The paranoid type is characterized by one or more delusions or frequent auditory hallucinations. The disorganized type has flat affect, chaotic behaviour, and incoherent speech. The catatonic type is characterized by psychomotor symptoms, and extreme negativism, muteness or echolalia. The undifferentiated type has symptoms of schizophrenia, but does not match any of the aforementioned types. The residual type is a less severe expression of schizophrenia with milder symptoms.

The prevalence of diagnosed schizophrenia in the population is 0.51% (Wu, Shi, Birnbaum, Hudson, & Kessler, 2006), but the prevalence of schizophrenia is probably higher because not everyone that suffers from schizophrenia has been diagnosed officially.

The main connection between religion and schizophrenia is through religious delusions and hallucinations. In the review by Gearing, Alonzo, Smolak, McHugh, Harmon, and Baldwin (in press), seventy studies that connect religion to schizophrenia were compared. They found that 43% of the studies reported religious or spiritual delusions and hallucinations in schizophrenic patients. Thirty studies focused on delusions and 90% of those found religious delusions in the patients. Thirteen studies also included hallucinations and 84.6% of these studies reported religious hallucinations the be a symptom. Delusions seem to be more common than hallucinations as a religious symptom in schizophrenia.

There are multiple classifications for the content of delusions. Some include religious delusions as a separate type, while others do not. In general, three types of delusions are known to have religious content in some patients. These types are persecutory delusions, grandiose delusions, and belittlement delusions (Siddle, Haddock, Tarrier, & Faragher, 2002). Persecutory delusions are delusions in which the patients believe that they are spied on, threatened, attacked, or otherwise persecuted by somebody (Comer, 2011b). In a religious context, patients may feel as if the Devil is persecuting them. In grandiose delusions, patients believe that they are very important people (Comer, 2011b), so they might believe they are God, a prophet, or somebody who has been sent by God. Delusions of belittlement are delusions in which the person feels that he or she is not important or unworthy, which might be in relation to the belief that he or she has sinned.

Since the review by Gearing et al. (in press) has only summarized studies in which the focus is on religion, a different study is necessary to show the prevalence of religious delusions and hallucinations among schizophrenic patients in general. Cannon and Kramer (in press) investigated the content of delusions in schizophrenic patients across a 100-year time span. They found that religious delusions were the second most common delusion content with 38% of the delusions having a religious content.

Suhail and Cochrane (2002) investigated 201 patients with schizophrenia and found that 22.9% suffered from religious delusions and 8% from religious hallucinations, which were all auditory hallucinations which they identified as the voice of God.

Siddle et al. (2002) studied 193 patients with schizophrenia and found that 23.3% of them suffered from religious delusions, which is very similar to the percentage found by Suhail and Cochrane (2002). The patients with religious delusions in the study by Siddle et al. (2002), suffered from mental health problems significantly longer than the patients without religious delusions. Some striking differences were found between patients with religious delusions and non-religious delusions that may point to the link between schizophrenia and hyper-religiosity. Patients with religious delusions reported a significantly higher religiosity, more conviction about their delusions and reported that they were more confident about the external origin of their hallucinations (e.g. God, Satan) as opposed to an internal origin. These observations are very similar to hyper-religiosity, since these patients showed higher religiosity in general, more conviction about the religious content of their delusion and often thought their hallucinations originated from God or another religious figure. Since people with religious delusions differ in these characteristics from people with non-religious delusions, it seems that these patients have characteristics of hyper-religiosity.

Since schizophrenic patients with religious delusions and hallucinations seem to be hyper-religious, this patient group will be used in the search for the neurobiological basis of hyper-religiosity. The neurobiological basis of schizophrenia in general is of less value, because the disorder is very heterogeneous.

Brain areas

Studies that investigate the biological basis of religious delusions are very scarce and the investigation of religious hallucinations is nonexistent. Hallucinations and delusions in general are associated with increased activation in the left parahippocampal gyrus and the left ventral striatum, and decreased activity in the right posterior cingulate (Liddle, Friston, Frith, Hirsch, Jones, & Frackowiak, 1992).

The only study that focuses specifically on religious delusions is from Puri, Lekh, Nijran, Bagary, and Richardson (2001). They used SPECT functional imaging on a schizophrenic patient with only religious delusions and found increased activation in the frontal and left temporal regions. Decreased activation was found in the occipital lobe, especially on the left side. The left temporal increase of activation is consistent with the general neurobiology of hallucinations and delusions found by Liddle et al. (1992).

Studies on white matter have not been done in patients with religious delusions or hallucinations, but they have been done in patients with schizophrenia in general. These white matter abnormalities can be linked to patients with religious delusions. Mendelsohn, Strous, Bleich, Assaf, and Hendler (2006) studied white matter abnormalities in schizophrenic patients. They found an overall decrease in white matter in the brain of patients with schizophrenia compared to healthy individuals. The decrease in white matter was most prominent in the prefrontal cortex and the temporal cortex. The authors also compared the mean white matter decrease and the severity of the symptoms, and they found a negative correlation between these two factors. This means that the less white matter in the brain, the more severe the symptoms are. Additionally, Siddle et al. (2002) compared the characteristics of schizophrenic patients with religious delusions and non-religious delusions and found that patients with religious delusions had decreased functioning, more medication use, and increased symptoms scores compared to patients with non-religious delusions. This points to more severe symptoms in patients with religious delusions, and thus probably less white matter in the brain.

Another study on white matter abnormalities in schizophrenia has been done by Hao et al. (2006). They found decreased white matter volume in the bilateral hippocampal gyrus, the bilateral precuneus, the right and left cuneus, the left fronto-orbital area, the right middle frontal lobe, the bilateral inferior temporal gyrus, the bilateral insula, and the right anterior cingulum. White matter increases have not been found in this study either, although other studies did find these increases (e.g. Federspiel, Begré, Kiefer, Schroth, Strik, & Dierks, 2006). Federspiel et al. (2006) found increases in white matter volume in the anterior thalamus, and the posterior part of the external capsule.

Grey matter alterations have also been linked to schizophrenia. Yamasaki et al. (2007) found that the grey matter volume and general volume of the planum temporale is reduced in patients with schizophrenia. The volume of the right planum temporale was correlated negatively with the severity of the symptoms, which means that the smaller the planum temporale, the more severe the delusional symptoms of the schizophrenic patients were. Since the symptoms of schizophrenic patients with religious delusions are more severe than those with non-religious delusions, the planum temporale might play a role in the neurobiology of religious delusions.

In another study (Whitford, Farrow, Williams, Gomes, Brennan, & Harris, 2009), grey matter volume in the medial frontal gyrus was positively correlated to symptoms severity in schizophrenia patients, although this region had significantly less grey matter volume compared to healthy controls. The authors explain this finding by saying that reduction of grey matter in this area leads to delusions, but extreme reductions of this area cannot produce an alteration of reality.

A different study which connects severity of delusions to brain areas has been done by Palaniyappan, Mallikarjun, Joseph, White, and Liddle (in press). They found bilateral grey matter volume reduction in the anterior cingulate and the anterior insula in schizophrenic patients in comparison to healthy individuals. The severity of the delusions was correlated negatively to the volume of the left anterior cingulate and the left anterior insula.

In summary, there is not much known on the specific areas involved in religious delusions and hallucinations, but based on symptom severity, some areas that may be of importance have been discovered. These areas are located mainly in the medial and lateral frontal lobe, but the temporal lobe has been implicated as well.

4. Temporal lobe epilepsy and hyper-religiosity

Epilepsy is a neurological disorder which is characterized by two or more seizures in a lifetime, which occur unprovoked. These seizures may vary in duration, intensity and frequency. A seizure occurs when groups of neurons fire excessively. The prevalence of epilepsy is between 0.4 and 1% of the world population and the incidence is between 0.04 and 0.07% (World Health Organization, 2009).

There are many forms of epilepsy, all with varying causes, localization and symptoms (Engel, 2001). The form of epilepsy which will be discussed in this chapter is temporal lobe epilepsy (TLE). TLE is a form of epilepsy in which the seizures are localized in the medial and/or lateral temporal lobe. The precise percentage of people with TLE is unknown, although it is suggested that TLE is the most common form of localized epilepsy (Wiebe, 2000).

Epilepsy has been linked to religion throughout history. Several important religious figures of different religions are said to have had epilepsy or seizures during their lives, including Buddha, Mohammed, St. Paul, and Julius Caesar, who was the highest religious figure in Rome (Devinsky & Lai, 2008). Even though some other forms of epilepsy have been linked to religion as well, TLE has been linked to religion most often (Ogata & Miyakawa, 1998; Devinsky & Lai, 2008). Additionally, TLE is the only form of epilepsy in which hyper-religiosity has been reported as a relatively common symptom associated with a personality disorder that occurs in TLE (Trimble & Freeman, 2006). This personality disorder will be discussed in more detail later and differs from the OCPD mentioned in the chapter on OCD. Because of the aforementioned connections between TLE, religiosity and hyper-religiosity, TLE is the only form of epilepsy that will be discussed in the context of hyper-religiosity.

There are multiple periods in TLE in which religious symptoms may occur. This can be during a seizure (ictal), after a seizure (postictal) and in between two seizures (interictal) (Devinsky & Lai, 2008). The religious experiences in the ictal, postictal and interictal seizures will be discussed next.

The religious experiences of patients with TLE can be divided in two categories. The first category are the ictus-related episodes. These are temporary religious symptoms occurring during and right after a seizure, thus in ictal and postictal seizures. The second category are the longer lasting religious symptoms which are present between two seizures (interictal) (Ogata & Miyakawa, 1998).

Ictal religious experiences may occur during ecstatic seizures and mostly last for a duration of a few seconds to a few minutes (Devinsky & Lai, 2008). An ecstatic seizure has been defined by Morgan (1990) and he describes this as feelings of pleasure, happiness, and contentment. He emphasizes that it is a temporal lobe seizure phenomenon, which is confirmed by Devinsky and Lai (2008). The nature of ecstatic seizures was investigated by Hansen and Brodtkorb (2003). They interviewed eleven patients with ecstatic seizures and found that five of them had religious or spiritual experiences during their seizure. In the study by Ogata and Miyakawa (1998), the prevalence of ictal religious experiences was 0.4% of all 234 epilepsy cases and 0.7% of the 137 patients with TLE. All cases of religious experiences in this study were in TLE patients, so the ictal related religious experiences were clearly linked to TLE in this study. In the review written by Devinsky and Lai (2008), it is stated that four out of five cases of ictal religious episodes described in literature, were related to temporal or frontotemporal localized seizures. These observations all point to the involvement of TLE in ictal religious experiences, even though it is not a very common phenomenon.

Postictal religious experiences are frequently related to postictal psychosis. Postictal psychosis is a psychosis of epilepsy which starts hours to days after the seizure (Devinsky & Lai, 2008). Postictal psychosis may have the following symptoms: auditory and visual hallucinations, delusions (which may be religious), paranoia, affective changes (mania) and aggression (Devinsky, 2008). Kanemoto, Kawasaki, and Kawai (1996) compared postictal

psychosis with interictal and chronic psychosis and concluded that postictal psychosis is distinguished from the other two types of psychosis by the presence of grandiose and religious delusions, and elevated moods. Dewhurst and Beard (1970) found that most sudden religiosity in epileptic patients occurred during the postictal period, and Ogata and Miyakawa (1998) found the prevalence of postictal psychosis among all the 234 epilepsy patients they studied to be 1.3% and among the TLE patients 2.2%. All cases of postictal psychosis were in TLE patients and 27.3% of these psychoses were religious. These studies all point to the postictal period of a seizure as an important period for religious experiences and TLE is again important.

Interictal seizures is the last period of epilepsy in which religiosity can be a symptom. Interictal religiosity is a more stable trait than the religious experiences in ictal and postictal seizures (Devinsky & Lai, 2008). It has been observed that some people, particularly those with TLE, can develop a personality disorder which includes hyper-religiosity (Trimble & Freeman, 2006). This personality disorder is also known as the Gastaut-Geschwind syndrome, named after the two researchers who first discovered this cluster of symptoms, and it is suggested that the prevalence of this disorder is 7% in TLE patients (Devinsky & Lai, 2008). Geschwind (1979) describes this personality disorder in detail and also states that this disorder has a higher prevalence in TLE compared to other forms of epilepsy. A few of the traits found in this personality disorder are increased concerns with religious issues (which is more often than not in contrast to the premorbid religious interest of the patient), a higher rate of religious conversions, hypergraphia (consisting of detailed writing, often with a religious or philosophical content), hyposexuality and irritability. This personality disorder can be assessed by the Bear-Fedio Inventory (Bear & Fedio, 1977).
A link between religious symptoms in interictal personality disorder and postictal psychosis has been found by Ogata and Miyakawa (1998), since all TLE cases in which interictal religiosity occurred, also suffered from postictal psychosis. This observation was confirmed by Trimble and Freeman (2006). Their study with TLE patients showed that more hyper-religious patients (as defined by the Bear-Fedio Inventory) had suffered from postictal psychosis compared to the non hyper-religious group.

Concluding, religious symptoms may occur either during, right after or in between seizures. Even though all are religious symptoms, the interictal religiosity is the state that resembles hyper-religiosity, as discussed here, the most. Both the ictal and postictal religious symptoms are temporary, even though some evidence has been found for the link between postictal psychosis and interictal religiosity. Since interictal religiosity is a longer-lasting disorder, just as hyper-religiosity, and postictal psychosis is observed as a frequently foregoing state, the brain areas involved in both these states will be discussed in the next section.

Brain areas

Postictal psychosis, as mentioned above, is a state that is frequently characterized by religious symptoms in TLE patients. A few studies have been done to investigate the neurological basis of this phenomenon. Marchetti et al. (2003) concluded that the left hippocampus volume was significantly smaller in the group with psychosis than in the control group. Also, 56% of the patients had atrophy in at least one structure, all of which had hippocampal atrophy, as compared to 10% of the controls. There were also a few patients with amygdala atrophy who also had hippocampal atrophy in the patient group.

In contrast, in the study done by Tebartz Van Elst et al. (2002) no hippocampal volume differences were observed between the three groups, but the amygdala was found to be enlarged on both sides of the brain in the group with psychosis. They also observed that the total brain volume of patients with TLE and psychosis was smaller than TLE patients without

psychosis and healthy controls, so more cerebral volume loss was observed in TLE patient with psychosis.

In a more thorough study done by Sundram et al. (2010), grey and white matter deficiencies were found in TLE patients with psychosis. In the inferior, middle and superior temporal gyri and fusiform gyri was a significant grey matter reduction as well as in the left parahippocampal gyrus and the left hippocampus. Grey matter reduction was also found outside the temporal lobe in the insula, cerebellum, caudate nucleus and in the right cingulum and left inferior parietal lobule. White matter reduction was found in the hippocampus, parahippocampal and fusiform gyri, middle and inferior temporal gyri, cingulum, corpus callosum, posterior thalamus, anterior limb of the internal capsule and the caudate nuclei. The left lingual gyrus and right midbrain and superior temporal gyrus also showed a significant white matter reduction.

The activity of brain structures in postictal psychosis has mostly been investigated in case-studies. Trimble and Freeman (2006) found that postictal psychosis was associated with bilateral changes in activity as opposed to unilateral changes and this has been confirmed by Devinsky (2008). Nishida et al. (2006) found increased blood-flow, and thus increased activity, in the ipsilateral temporal and/or frontal lobes in postictal psychosis. Hippocampal sclerosis was also found. The results from the study of Leutmezer et al. (2003) confirm the increased activity in the temporal (medial and inferior) and frontal lobes. In a study by Fong, Ho, Tsoi, Fong, and Ho (2002), increased activity was also found in the lateral temporal cortex. All these studies seem to point to the importance of hyperactivity in postictal psychosis, especially the activation of temporal areas.

Interictal religiosity resembles hyper-religiosity the most out of the ictal, postictal and interictal episodes of epilepsy, but there has not been done much research on the brain areas involved in interictal religiosity. One study by Wuerfel et al. (2004) compared the size of medial temporal structures in patients with and without hyper-religiosity. They found that patients who scored higher on a religiosity rating, had a smaller right hippocampus. Religiosity was negatively correlated to hippocampal volume.

Regrettably, no more studies on the neurobiological basis of interictal religiosity could be found. Regardless, the personality disorder related to hyper-religiosity in interictal seizures has been associated with TLE. Therefore we can assume that lateral and medial temporal areas are also important in interictal religiosity. Furthermore, because postictal psychosis often occurs prior to interictal religiosity, it may also be possible that hyperactivation in these lateral and medial structures is involved in interictal religiosity, just like in postictal psychosis.

The prefrontal cortex is also an area that might be involved in interictal religiosity. Since hyper-religiosity is a symptom of a presumed personality disorder, and personality disorders have been linked to the dysfunctioning of the prefrontal cortex or frontal subcortical structures (Chow, 2000), it could be possible that the prefrontal cortex is also involved in hyper-religiosity in interictal religiosity.

In summary, the most important brain areas that are involved in religiosity in TLE are medial and lateral temporal lobe areas, although some areas outside the temporal lobe were also found to be involved.

5. Mania and hyper-religiosity

Mania is the final disorder that will be discussed in the light of hyper-religiosity. Mania is a mood disorder. A manic episode is a mood episode which is a symptom of bipolar I disorder, in which episodes of depression and mania alternate. According to the *DSM-IV-TR* (2000), a manic episode is a period in time with a constant abnormal, irritable or elevated mood, which lasts at least one week. During this episode, three or more of the following symptoms are present: grandiosity and/or high self-esteem, less need for sleep, more talkative, racing thoughts, easily distractible, more goal-directed activity or psychomotor agitation, and/or involvement in pleasurable activities with negative consequences. A manic episode is also characterized by occupational, social, and/or relational dysfunctioning and the symptoms are not the consequence of drug use or illness. The lifetime prevalence of bipolar I disorder, in which manic episodes occur, is 0.6% (Merikangas et al, 2011).

Even though there has not been done much research on the connection between mania and religiosity, two reports clearly show this link does exist. Whitney (1998) reported a case study of a man who had severe religious symptoms during a manic episode. He saw angels and felt connected to heaven and God. Moreover, in a study to investigate the phenomenology of bipolar I disorder by Jerrell and Shugart (2004), it was found that 18.5% of the 184 adult patients showed hyper-religiosity as a symptom.

These studies show that there are not only reports of hyper-religiosity in mania, but that it is also quite common among this patient group. There is no literature available which links hyper-religious symptoms in mania to specific brain areas. Therefore, the brain areas that will be discussed in the next section will all be from research on mania and bipolar I disorder in general.

Brain areas

Mania is associated with both white and grey matter abnormalities and functional abnormalities. The white and grey matter abnormalities will be discussed first.

Adler et al. (2004) investigated the white matter density in frontal tracts and found that the anterior commissure had a reduced white matter volume compared to healthy persons. Another connection between the two hemispheres that has been investigated for abnormalities in bipolar disorder is the corpus callosum. Atmaca, Ozdemir, and Yildirim (2007) have found the corpus callosum to be smaller among people with bipolar I disorder than in healthy controls. They found significant reduction in volume in the anterior part, the posterior part and the part between the middle and the posterior part (called isthmus).

Liu, Chen, Hsieh, Su, Yeh, and Chen (2010) studied the differences in white matter abnormalities between bipolar I disorder and bipolar II disorder and compared them with healthy control subjects. It was found that people with bipolar I disorder had significantly less white matter volume in the thalamus, the anterior cingulum, and the inferior frontal gyrus compared to healthy individuals. The inferior frontal gyrus was found to be smaller in bipolar II disorder compared to bipolar I disorder.

Mahon et al. (2009) found that some subcortical regions are also affected in bipolar disorder. Mainly the white matter tracts between the hippocampus and amygdala showed less white matter volume in their study compared to healthy individuals.

In the review article written by Heng, Song, and Sim (2010), white matter abnormalities of 18 different studies have been combined. They found some areas which were especially prominent in their white matter volume reductions. These were the corpus callosum, the prefrontal lobe specifically and the frontal lobe in general, and the internal capsule. They summarized that white matter abnormalities have been prominent in many studies in the frontal and prefrontal lobes, but reports about the parietal, temporal and occipital lobes and subcortical areas have not been consistent and are sometimes contradictory.

Haller et al. (in press) investigated grey and white matter abnormalities in patients with bipolar disorder. They found a decrease of white matter in the corpus callosum. They also found some areas in the brain with significant grey matter reduction. These areas are the right anterior insula, the head of the caudate nucleus, the nucleus accumbens, the ventral putamen and the frontal orbital cortex. There was no increase in grey matter in any brain area.

In a study by Beyer, Kuchibhatla, Payne, MacFall, Cassidy, and Krishnan (2009), grey and white matter volumes were also investigated in patients with bipolar disorder. They found no differences in total grey matter volume in bipolar disorder patients compared to healthy controls or in total white matter volume. They did find smaller grey matter volumes in the inferior frontal areas. Significant white matter abnormalities were not found in specific areas.

In contrast to Beyer et al. (2009), Adler, DelBello, Jarvis, Levine, Adams, and Strakowski (2007) found increased grey matter volume in the left thalamus, the right middle and superior temporal gyri and the left fusiform gyrus, posterior cingulate and paracentral lobule. Increases in grey matter volume were also found in the cerebellum. Increases in grey matter density were observed in people with bipolar I disorder as well. This was in the anterior cingulate cortex, right middle temporal gyrus, posterior cingulate cortex, inferior parietal lobule, superior parietal lobule, and precuneus. In the right precentral gyrus and the right fusiform gyrus, increased grey matter density was also observed.

Bhardwaj, Chakrabarti, Mittal, and Sharan (2010) investigated the difference in activity level of different brain areas between patients with mania, bipolar depression, unipolar depression and controls. Patients with mania had significantly lower activity compared to healthy controls in the left anterior cingulate cortex, the left frontal cortex and the left parietal cortex.

Culha et al. (2008) also investigated cerebral blood flow in bipolar disorder. The blood flow was lower in the medial-basal temporal area, in the occipital area, the medial frontal area, the parietal area and the cingulate gyrus.

In a quantitative meta-analysis of 65 fMRI studies in bipolar disorder by Chen, Suckling, Lennox, Ooi, and Bullmore (2011), a summary is given of specific brain areas and their activation in bipolar disorder. The inferior frontal cortex and the putamen are two areas that were underactivated in patients with bipolar disorder compared to healthy individuals. The basal ganglia and medial temporal structures like the parahippcampal gyrus, the hippocampus and the amygdala on the other hand, were found to be overactivated compared to healthy controls.

In summary, the frontal areas and the limbic system are linked to mania most consistently in these studies, although the other lobes have been implicated as well.

6. Integration

After discussing all four disorders associated with hyper-religiosity, this chapter will contain the integration of the neurobiological information gathered about those disorders. The brain areas associated with each disorder are summarized in table 1 and table 2, which are presented in the appendix.

The first feature that all four disorders have in common is the general white matter atrophy in (parts of) the brain. This means there are less strong connections between brain structures and thus impaired communication between certain structures. In general, hyper-religiosity seems to be a disorder which is partly caused by white matter loss and so less connectivity between brain areas.

Many deviances in the frontal lobes are found in the four disorders. OCD, schizophrenia, and mania all have decreased white and grey matter compared to healthy individuals in the frontal lobes. These changes in white and grey matter are not found in TLE. However, TLE is associated with increased activity and blood flow in the frontal lobes, just like OCD and schizophrenia. In contrast, mania only has decreased activity in frontal structures. Even though not all four disorders have the same deviances in the frontal lobes, they all seem to have impaired functioning of this area of the brain. This suggests that the frontal lobes are probably involved in hyper-religiosity. The general function of the frontal lobes is executive functioning (e.g. planning, inhibiting unwanted behaviour) (Kolb & Whishaw, 2003), but different parts of the frontal lobes are involved in different functions. Changes in the prefrontal cortex, for example, are linked to personality changes (Chow, 2000). The decreases in white and grey matter and the increases in activity in the prefrontal cortex are found in all four disorders. This might point to a general personality change in hyper-religiosity. This personality change has been suggested already in the interictal period of TLE and these findings might suggest that a personality change occurs in hyper-religiosity, also in the other three disorders discussed.

The temporal lobes also seem to play an important role in the four disorders. Decreases in grey and white matter are found in OCD, schizophrenia and TLE. In mania, only increases in grey matter were found in the temporal lobes and no alterations in white matter. The activity of the temporal lobes is increased in schizophrenia, TLE and mania, but no activity changes have been found in OCD. This observation might be due to the differences in circumstances between hyper-religiosity in OCD and schizophrenia, TLE, and mania. Hyper-religiosity in schizophrenia, TLE, and mania all seem to be triggered by a psychosis (in TLE and schizophrenia) or lack of contact with reality (in mania, during which a person believes he or she can do anything or believes he or she is very important). Liddle et al. (1992), discovered that increased activity in the left medial temporal areas are involved in hallucinations and delusions (loss of contact with reality). This may explain why the increase in activity in the temporal lobes is not found in OCD, but is found in the other three disorders. Kolb and Whishaw (2003) also emphasize the involvement of the temporal lobes in auditory and visual perceptions. The religious hallucinations in TLE and schizophrenia may be explained by the involvement of the temporal lobes. Changes in personality are also linked to the dysfunctioning of the temporal lobes. In combination with the prefrontal disturbances found in the disorders, the personality change involved in hyper-religiosity is plausible.

Parts of the parietal lobes have less white or grey matter in OCD, schizophrenia and TLE and again mania only has increased grey matter. Regarding activity, only OCD shows increases in activity in the parietal lobes and only mania decreased activity on the left side. These inconsistent and scarce findings of the involvement on the parietal lobes suggest that the parietal lobes might not be very much involved in hyper-religiosity. The parietal lobes are mostly involved in visual and spatial tasks, and movement (Kolb & Whishaw, 2003). These functions do not seem to be impaired in hyper-religiosity, and therefore the involvement of

the parietal lobes seems unlikely in hyper-religiosity. This is confirmed by the scarce findings about the dysfuctioning of the parietal lobes in the four disorders.

The occipital lobes are also not as widely implied in the four disorders as the frontal and temporal lobes. Small parts of this area in the brain show less white matter in OCD, schizophrenia and TLE. No grey matter alterations are found. Decreased activity is found in both schizophrenia and mania, but not in OCD and TLE. These observations suggest that the occipital lobes play a small role, or no role at all in hyper-religiosity. The function of the occipital lobes confirm this absence of a relation to hyper-religiosity. Their function is mainly visual (Kolb & Whishaw, 2003), and vision is not disturbed in hyper-religiosity.

The most widely implied brain network in all four disorders is the limbic system. The limbic system consists of many structures. Some of these are the amygdala, the hippocampus, the cingulate gyrus, the isthmus, and the thalamus. Decreases in white matter are found in all four disorders throughout the limbic system. Decreases in grey matter have also been found in some areas. All disorders also show increased activity in some parts of the limbic system, indicating that this system might be dysfunctioning in all disorders. The limbic system thus seems to be involved in all disorders and therefore it can be assumed that this system is also involved in hyper-religiosity. This assumption is supported by the fact that the limbic system is involved in emotions (Kolb & Whishaw, 2003). Hyper-religiosity is more a feeling than a rational choice for the patients. They may feel connected to God or feel happy to be in his presence. Fear and happiness are two emotions that are often named in the context of hyper-religiosity. So the involvement of the emotional network is highly plausible in hyper-religiosity. The ventromedial prefrontal cortex is also suggested to be involved in the limbic system (Kolb & Whishaw, 2003). This cortical part of the limbic system is often called the paralimbic system. Since the activity of this structure is also elevated in the four disorders, the emotional system might be the most prominent structure involved in hyper-religiosity.

The findings about the basal ganglia are inconsistent across the disorders. Some disorders show increased grey matter, while others show decreased grey matter. The activity of structures of the basal ganglia are also inconsistent. The basal ganglia's main functions are movement and stimulus-response learning (Kolb & Whishaw, 2003). These are not functions that are implied in hyper-religiosity, so the basal ganglia being uninvolved in the four disorders is not unexpected.

Subcortical areas that are involved in the four disorders are all white matter tracts that connect important parts of the brain. The corpus callosum and the anterior commissure have decreased white matter in either OCD, TLE, mania or in more than one of these disorders. The corpus callosum and the anterior commissure connect the two hemispheres of the brain. White matter abnormalities were not observed in schizophrenia. It seems that the disruption of white matter connections within the brain (through several subcortical areas) is also a central feature in the disorders in which hyper-religiosity occurs.

The cerebellum and the brain stem have also been implied inconsistently in the four disorders. In schizophrenia, there are no observations about these areas being involved and the observations in the other disorders are not consistent. Therefore it may be assumed that these areas are not important in hyper-religiosity.

In conclusion, the frontal lobes (especially the prefrontal area), the temporal lobes and the limbic system are the main areas of the brain that seem to be involved in hyper-religiosity. White matter deficiencies are also found in all four disorders throughout the brain, which suggests a general atrophy of connections of networks within the brain.

7. Discussion

Following the comparison of the brain structures involved in OCD, schizophrenia, TLE, and mania in the previous chapter, a few brain regions were found to likely be involved in hyper-religiosity. These brain areas are the frontal lobes (especially the prefrontal area), the temporal lobes, and the limbic system. The general white matter atrophy in all four disorders was also a striking finding, which suggests that there are less strong connections within the brains of patients with hyper-religiosity.

Because the research done on hyper-religiosity is very scarce, the four disorders in which hyper-religiosity has been observed were compared to find the brain structures that are likely to be involved in this disorder. However, this method is obviously not without flaws. Religious symptoms are of course not the only symptoms that the four disorders have in common, so the brain areas found might also be the neurobiological basis of other symptoms or characteristics of the disorders. Moreover, the brain areas that overlap in the four disorders are general and large areas of the brain, which are functionally heterogeneous. No small and functionally homogeneous structures were found to overlap in all disorders. This might be because the four disorders have many differences, and therefore only heterogeneous areas of overlap exist. Another limitation of the method used here is that the brain areas found in the disorders separately, more often than not were brain areas involved generally in the disorder, instead of being specifically involved in the religious symptoms of the disorder. Small samples sizes of the studies are also a problem.

However, to uncover the neurobiological basis of hyper-religiosity, one must begin to make a general overview of the brain areas that might be involved. This has been done in this study and with this information, others might investigate and find more specific brain areas being involved in this disorder.

As interesting notion, now that the neurobiological basis of hyper-religiosity has been uncovered, is the comparison between the brain areas involved in hyper-religiosity and regular religiosity. An fMRI study has been done by Beauregard and Paquette (2006), in which the brain activity of nuns was measured during a religious experience. Increased activation was measured in many brain structures. The brain areas which were activated during this regular expression of religion and were also found to be involved in hyper-religiosity were the right medial orbitofrontal cortex, the right middle temporal cortex, the left medial prefrontal cortex, the left anterior cingulate cortex, and the left insula. These are all areas of the frontal and temporal lobes, and the paralimbic system. Some areas that were also involved in the regular expression of religion, but not in hyper-religiosity were the left and right inferior parietal cortex, the right superior parietal cortex, the caudate nucleus and the left brainstem.

In another study (Newberg, Pourdehnad, Alavi, & d'Aquili, 2003), the cerebral blood flow was measured during meditative prayer. The increased blood flow observed in this study was in the prefrontal cortex, the inferior parietal lobes, and the inferior frontal lobes. Again, the parietal cortex is not found to be involved in hyper-religiosity, but the frontal cortex is.

A final study on brain activation during regular religious experiences has been done by Azari et al. (2001). They found that the dorsolateral prefrontal cortex, the dorsomedial frontal cortex, the left cerebellum and the right precuneus showed increased activation during religious experiences. The frontal lobes are implied again, just like a part of the right parietal lobe and the cerebellum. The frontal lobes are the only area that is also involved in hyper-religiosity.

In these three studies on the neurobiological basis of regular religiosity, the frontal lobes are consistently implicated, whereas parts of the paralimbic system and temporal lobes were implicated in only one study. Areas that are involved in the regular expression of religion but not in hyper-religiosity are the parietal lobes, and possibly part of the basal ganglia and the

cerebellum. These findings suggest that there is some overlap in the neurological basis of regular religiosity and hyper-religiosity (namely the frontal lobes, and possibly the temporal lobes and limbic system), but that there are also differences (like the obvious involvement of the parietal lobes, and probably some subcortical structures). Hyper-religiosity thus seems to be a disorder which has some overlap with regular religiosity, but there are also striking differences, both in the phenomenology and the neurobiological basis.

8. Summary

By comparing the neurobiological basis of OCD, schizophrenia, TLE, and mania, the neurobiological basis of hyper-religiosity has been provisionally uncovered. The brain areas that are involved in hyper-religiosity are the frontal lobes (especially the prefrontal area), the temporal lobes, and the limbic system. Also, a general white matter atrophy was found in all four disorders, which suggests that there are less strong connections between brain areas in hyper-religiosity. Other areas of the brain, like the parietal and occipital lobes, other subcortical areas, the cerebellum, and the brainstem were involved in some but not all of the four disorders. These brain areas showed inconsistent results across the four disorders, and therefore were not concluded to be involved in hyper-religiosity. Sadly, no specific areas of the brain were found to be involved in all four disorders. Only general, large, and functionally heterogeneous areas overlapped in OCD, schizophrenia, TLE, and mania. Even though this is a limitation of the method used, the results from this study may be used to uncover more specific areas involved in hyper-religiosity.

9. References

Adler, C. M., DelBello, M. P., Jarvis, K., Levine, A., Adams, J., & Strakowski, M. (2007). Voxel-based study of structural changes in first-episode patients with bipolar disorder. *Biological Psychiatry, 61*, 776 – 781.

Adler, C. M., Holland, S. K., Schmithorst, V., Wilke, M., Weiss, K. L., Pan, H., et al. (2004). Abnormal frontal white matter tracts in bipolar disorder: A diffusion tensor imaging study. *Bipolar Disorders, 6*, 197 – 203.

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text rev.). Washington, DC: Author.

Angst, J., Gamma, A., Endrass, J., Goodwin, R., Ajdacic, V., Eich, D., et al. (2004). Obsessive-compulsive severity spectrum: Prevalence, comorbidity, and course. *European Archives of Psychiatry and Clinical Neuroscience, 254*, 156 – 164.

Aouizerate, B., Guehl, D., Cuny, E., Rougier, A., Bioulac, B., Tignol, J., et al. (2004). Pathophysiology of obsessive-compulsive disorder: A necessary link between phenomenology, neuropsychology, imagery and physiology. *Progress in Neurobiology, 72*, 195 – 221.

Atmaca, M., Ozdemir, H., & Yildirim, H. (2007). Corpus callosum areas in first-episode patients with bipolar disorder. *Psychological Medicine, 37*, 699 – 704.

Azari, N. P., Nickel, J., Wunderlich, G., Niedeggen, M., Hefter, H., Tellmann, L., et al. (2001). Neural correlates of religious experience. *European Journal of Neuroscience, 13*, 1649 – 1652.

Bear, M. D., & Fedio, P. (1977). Quantitative analysis of interictal behavior in temporal lobe epilepsy. *Archives of Neurology, 34*(8), 454 – 467.

Beauregard, M., & Paquette, V. (2006). Neural correlates of a mystical experience in Carmelite nuns. *Neuroscience Letters, 405*, 186 – 190.

Beyer, J. L., Kuchibhatla, M., Payne, M. E., MacFall, J., Cassidy, F., & Krishnan, K. R. R. (2009). Gray and white matter brain volumes in older adults with bipolar disorder. *International Journal of Geriatric Psychiatry, 24*, 1445 – 1452.

Bhardwaj, R., Chakrabarti, S., Mittal, B. R., & Sharan, P. (2010). A single photon emission computerized tomography (SPECT) study of regional cerebral blood flow in bipolar disorder. *The World Journal of Biological Psychiatry, 11*(2), 334 – 343.

Boyer, P. (2001). *Religion explained: The evolutionary origins of religious thought.* New York: Basic Books.

Cannon, B. J., & Kramer, L, M. (in press). Delusion content across the 20th century in an American psychiatric hospital. *International Journal of Social Psychiatry.*

Chen, C.-H., Suckling, J., Lennox, B. R., Ooi, C., & Bullmore, E. T. (2011). *Bipolar Disorders, 13*, 1 – 15.

Chow, T. W. (2000). Personality in frontal lobe disorders. *Current Psychiatry Reports, 2*(5), 446 – 451.

Comer, R. J. (2011a). Anxiety disorders. In, *Fundamentals of abnormal psychology* (6th ed., pp. 94 – 131). New York: Worth Publishers.

Comer, R. J. (2011b). Schizophrenia. In, *Fundamentals of abnormal psychology* (6th ed., pp. 356 – 391). New York: Worth Publishers.

Culha, A. F., Osman, O., Dogangün Y., Filiz, K., Suna, K., Kalkan, O. N., et al. (2008). Changes in regional cerebral blood flow demonstrated by ^{99m}Tc-HMPAO SPECT in euthymic bipolar patients. *European Archives of Psychiatry and Clinical Neuroscience, 258*, 144 – 151.

Denys, D., De Geus, F., Van Megen, H. J. G. M., & Westenberg, H. G. M. (2004). Use of factor analysis to detect potential phenotypes in obsessive-compulsive disorder. *Psychiatry Research, 128,* 273 – 280.

Devinsky, O. (2008). Postictal psychosis: Common, dangerous, and treatable. *Epilepsy Currents, 8*(2), 31 – 34.

Devinsky, O., & Lai, G. (2008). Spirituality and religion in epilepsy. *Epilepsy & Behavior, 12*, 636 – 643.

Dewhurst, K., & Beard, A. W. (1970). Sudden religious conversions in temporal lobe epilepsy. *British Journal of Psychiatry, 117*, 497 – 507.

Eisen, J. L., Goodman, W. K., Keller, M. B., Warshaw, M. G., DeMarco, L. M., Luce, D. D., et al. (1999). Patterns of remission and relapse in obsessive-compulsive disorder: A 2-year prospective study. *Journal of Clinical Psychiatry, 60*, 346 – 351.

Engel, J., Jr. (2001). A proposed diagnostic scheme for people with epileptic seizures and with epilepsy: Report of the ILAE task force on classification and terminology. *Epilepsia, 42*(6), 796 – 803.

Federspiel, A., Begré, S., Kiefer, C., Schroth, G., Strik, W. K., & Dierks, T. (2006). Alterations of white matter connectivity in first episode schizophrenia. *Neurobiology of Disease, 22*, 702 – 709.

Fong, G. C. Y., Ho, W. Y., Tsoi, T. H., Fong, K. Y., & Ho, S. L. (2002). Lateral temporal hyperperfusion in postictal psychosis assessed by 99mTc-HMPAO SPECT. *NeuroImage, 17*, 1634 – 1637.

Fontenelle, L. F., Harrison, B. J., Yücel, M., Pujol, J., Fujiwara, H., & Pantelis, C. (2009). Is there evidence of brain white-matter abnormalities in obsessive-compulsive disorder?: A narrative review. *Topics in Magnetic Resonance Imaging, 20*, 291 – 298.

Gearing, R. E., Alonzo, D., Smolak, A., McHugh, K., Harmon, S., & Baldwin, S. (in press). Association of religion with delusions and hallucinations in the context of schizophrenia: Implications for engagement and adherence. *Schizophrenia Research.*

Geschwind, N. (1979). Behavioural changes in temporal lobe epilepsy. *Psychological Medicine, 9*, 217 – 219.

Greenberg, D., & Shefler, G. (2002). Obsessive compulsive disorder in ultra-orthodox Jewish patients: A comparison of religious and non-religious symptoms. *Psychology and Psychotherapy: Theory, Research and Practice, 75*, 123 – 130.

Haller, S., Xekardaki, A., Delaloye, C., Canuto, A., Lövblad, K. O., Gold, G., et al. (in press). Combined analysis of grey matter voxel-based morphometry and white matter tract-based spatial statistics in late-life bipolar disorder. *Journal of Psychiatry & Neuroscience.*

Hansen, B. A., & Brodtkorb, E. (2003). Partial epilepsy with "ecstatic" seizures. *Epilepsy & Behavior, 4*, 667 – 673.

Hao, Y., Liu, Z., Jiang, T., Gong, G., Liu, H., Tan, L., et al. (2006). White matter integrity of the whole brain is disrupted in first-episode schizophrenia. *Developmental Neuroscience, 17*(1), 23 – 26.

Heng, S., Song, A. W., & Sim, K. (2010). White matter abnormalities in bipolar disorder: Insights from diffusion tensor imaging studies. *Journal of Neural Transmission, 117*, 639 – 654.

Jerrell, J. M., & Shugart, M. A. (2004). A comparison of the phenomenology and treatment of youths and adults with bipolar I disorder in a state mental health system. *Journal of Affective Disorders, 80*, 29 – 35.

Kanemoto, K., Kawasaki, J., & Kawai, I. (1996). Postictal psychosis: A comparison with acute interictal and chronic psychoses. *Epilepsia, 37*(6), 551 – 556.

Kolb, B., & Whishaw, I. Q. (2003). *Fundamentals of human neuropsychology* (6th ed.). New York: Worth Publishers.

Kolb, B., & Whishaw, I. Q. (2006). How does the nervous system function? In, *An introduction to brain and behavior* (2nd ed., pp. 34-73). New York: Worth Publishers.

Kopřivová, J., Horáček, J., Tintěra, J., Praško, J., Raszka, M., Ibrahim, I., et al. (2009). Medial frontal and dorsal cortical morphometric abnormalities are related to obsessive-compulsive disorder. *Neuroscience Letters, 464*, 62 – 66.

Leutmezer, F., Podreka, I., Asembaum, S., Pietrzyk, U., Lucht, H., Back, C., et al. (2003). Postictal psychosis in temporal lobe epilepsy. *Epilepsia, 44*(4), 582 – 590.

Liddle, P. F., Friston, K. J., Frith, C. D., Hirsch, S. R., Jones, T., & Frackowiak, R. S. (1992). Patterns of cerebral blood flow in schizophrenia. *The British Journal of Psychiatry, 160*, 179 – 186.

Liu, J.-X., Chen, Y.-S., Hsieh, J.-C., Su, T.-P., Yeh, T.-C., & Chen, L.-F. (2010). Differences in white matter abnormalities between bipolar I and II disorders. *Journal of Affective Disorder, 127*, 309 – 315.

Mahon, K., Wu, J., Malhotra, A. K., Burdick, K. E., DeRosse, P., Ardekani, B. A., et al. (2009). A voxel-based diffusion tensor imaging study of white matter in bipolar disorder. *Neuropsychopharmacology, 34*(6), 1590 – 1600.

Marchetti, R. L., Azevedo, D., Jr., de Campos Bottino, C. M., Kurcgant, D., de Fátima Horvath Marques, A., Marie, S. K. N., et al. (2003). Volumetric evidence of a left laterality effect in epileptic psychosis. *Epilepsy & Behavior, 4*, 234 – 240.

Mataix-Cols, D., Rauch, S. L., Baer, L., Eisen, J. L., Shera, D. M., Goodman, W. K., et al. (2002). Symptom stability in adult obsessive-compulsive disorder: Data from a naturalistic two-year follow-up study. *American Journal of Psychiatry, 159*, 263 – 268.

Mendelsohn, A., Strous, R. D., Bleich, M., Assaf, Y., & Hendler, T. (2006). Regional axonal abnormalities in first episode schizophrenia: Preliminary evidence based on high b-value diffusion-weighted imaging. *Psychiatry Research: Neuroimaging, 146*, 223 – 229.

Menzies, L., Chamberlain, S. R., Laird, A. R., Thelen, S. M., Sahakian, B. J., & Bullmore, E. T. (2008). Integrating evidence from neuroimaging and neuropsychological studies of obsessive-compulsive disorder: The orbitofronto-striatal model revisited. *Neuroscience and Biobehavioral Reviews, 32*, 525 – 549.

Merikangas, K. R., Jin, R., He, J-P., Kessler, R. C., Lee, S., Sampson, N. A., et al. (2011). Prevalence and correlates of bipolar spectrum disorder in the world mental health survey initiative. *Archives of General Psychiatry, 68*(3), 241 – 251.

Miller, C. H., & Hedges, D. W. (2008). Scrupulosity disorder: An overview and introductory analysis. *Journal of Anxiety Disorders, 22*, 1042 – 1058.

Morgan, H. (1990). Dostoevsky's epilepsy: A case report and comparison. *Surgical Neurology, 33*, 413 – 416.

Nakamae, T., Narumoto, J., Sakai, Y., Nishida, S., Yamada, K. Nishimura, T., et al. (in press). Diffusion tensor imaging and tract-based spatial statistics in obsessive-compulsive disorder. *Journal of Psychiatric Research.*

Nelson, E. A., Abramowitz, J. S., Whiteside, S. P., & Deacon, B. J. (2006). Scrupulosity in patients with obsessive-compulsive disorder: Relationship to clinical and cognitive phenomena. *Anxiety Disorders, 20*, 1071 – 1086.

Newberg, A., Pourdehnad, M., Alavi, A., & d'Aquili, E. G. (2003). Cerebral blood flow during meditative prayer: Preliminary findings and methodological issues. *Perceptual and Motor Skills, 97*(2), 625 – 630.

Nishida, T., Kudo, T., Inoue, Y., Nakamura, F., Yoshimura, M., Matsuda, K., et al. (2006). Postictal mania versus postictal psychosis: Differences in clinical features, epileptogenic zone, and brain functional changes during postictal period. *Epilepsia, 47*(12), 2104 – 2114.

Ogata, A., & Miyakawa, T. (1998). Religious experiences in epileptic patients with a focus on ictus-related episodes. *Psychiatry and Clinical Neurosciences, 52*, 321 – 325.

Olatunji, B. O., Abramowitz, J. S., Williams, N. L., Connolly, K. M., & Lohr, J. M. (2007). Scrupulosity and obsessive-compulsive symptoms: Confirmatory factor analysis and validity of the Penn Inventory of Scrupulosity. *Journal of Anxiety Disorders, 21*, 771 – 787.

Palaniyappan, L., Mallikarjun, P., Joseph, V., White, T. P., & Liddle, P. F. (in press). Reality distortion is related to the structure of the salience network in schizophrenia. *Psychological Medicine.*

Puri, B. K., Lekh, S. K., Nijran, K. S., Bagary, M. S., & Richardson, A. J. (2001). SPECT neuroimaging in schizophrenia with religious delusions. *International Journal of Psychophysiology, 40*, 143 – 148.

Rotge, J.-Y., Langbour, N., Guehl, D., Bioulac, B., Jaafari, N., Allard, M., et al. (2010). Gray matter alterations in obsessive-compulsive disorder: An anatomic likelihood estimation meta-analysis. *Neuropsychopharmacology, 35*, 686 – 691.

Sedikides, C., & Gebauer, J. E. (2010). Religiosity as self-enhancement: a meta-analysis of the relation between socially desirable responding and religiosity. *Personality and Social Psychology Review, 14*(1), 17 – 36.

Siddle, R., Haddock, G., Tarrier, N., & Faragher, E. B. (2002). Religious delusions in patients admitted to hospital with schizophrenia. *Social Psychiatry and Psychiatric Epidemiology, 37*, 130 – 138.

Suhail, K., & Cochrane, R. (2002). Effect of culture and environment on the phenomenology of delusions and hallucinations. *International Journal of Social Psychiatry, 48*(2), 126 – 138.

Sundram, F., Cannon, M., Doherty, C. P., Barker, G. J., Fitzsimons, M., Delanty, N., et al. (2010). Neuroanatomic correlates of psychosis in temporal lobe epilepsy: Voxel-based morphometry study. *The British Journal of Psychiatry, 197*, 482 – 492.

Szeszko, P. R., Ardekani, B. A., Ashtari, M., Malhotra, A. K., Robinson, D. G., Bilder, R. M., et al. (2005). White matter abnormalities in obsessive-compulsive disorder: A diffusion tensor imaging study. *Archives of General Psychiatry, 62*, 782 – 790.

Szeszko, P. R., MacMillan, S., McMeniman, M., Chen, S., Baribault, K., Lim, K. O., et al. (2004). Brain structural abnormalities in psychotropic drug-naive pediatric patients with obsessive-compulsive disorder. *American Journal of Psychiatry, 161*, 1049 – 1056.

Tebartz van Elst, L. T., Baeumer, D., Lemieux, L., Woermann, F. G., Koepp, M., Krishnamoorthy, S., et al. (2002). Amygdala pathology in psychosis of epilepsy: A magnetic resonance imaging study in patients with temporal lobe epilepsy. *Brain, 125*, 140 – 149.

Tek, C., & Ulug, B. (2001). Religiosity and religious obsessions in obsessive-compulsive disorder. *Psychiatry Research, 104*, 99 – 108.

Tolin, D. F., Abramowitz, J. S., Kozak, M. J., & Foa, E. B. (2001). Fixity of belief, perceptual aberration, and magical ideation in obsessive-compulsive disorder. *Anxiety Disorders, 15*, 501 – 510.

Trimble, M., & Freeman, A. (2006). An investigation of religiosity and the Gastaut-Geschwind syndrome in patients with temporal lobe epilepsy. *Epilepsy & Behavior, 9*, 407 – 414.

Vail, K. E., Rothschild, Z. K., Weise, D. R., Solomon, S., Pyszczynski, T., & Greenberg, J. (2010). A terror management analysis of the psychological functions of religion. *Personality and Social Psychology Review, 14*(1), 84 – 94.

Whitford, T. J., Farrow, T. F. D., Williams, L. M., Gomes, L., Brennan, J., & Harris, A. W. F. (2009). Delusions and dorso-medial frontal cortex volume in first-episode schizophrenia: A voxel-based morphometry study. *Psychiatry Research: Neuroimaging, 172*, 175 – 179.

Whitney, E. (1998). Mania as spiritual emergency. *Psychiatric Services, 49*(12), 1547 – 1548.

Wiebe, S. (2000). Epidemiology of temporal lobe epilepsy. *The Canadian Journal of Neurological Sciences, 27*(Suppl. 1), S6 – S10.

World Health Organization (2009, January). *Epilepsy fact sheet No 999.* Retrieved April 29, 2011, from http://www.who.int/mediacentre/factsheets/fs999/en/index.html

Wu, E. Q., Shi, L., Birnbaum, H., Hudson, T., & Kessler, R. (2006). Annual prevalence of diagnosed schizophrenia in the USA: A claims data analysis approach. *Psychological Medicine, 36*, 1535 – 1540.

Wuerfel, J., Krishnamoorthy, E. S., Brown, R. J., Lemieux, L., Koepp, M., Tebartz van Elst, L., et al. (2004). *Journal of Neurology, Neurosurgery & Psychiatry, 75*, 640 – 642.

Yamasaki, S., Yamasue, H., Abe, O., Yamada, H., Iwanami, A., Hirayasu, Y., et al. (2007). Reduced planum temporale volume and delusional behaviour in patients with schizophrenia. *European Archives of Psychiatry and Clinical Neuroscience, 257*, 318 – 324.

Ysseldyk, R., Matheson, K., & Anisman, H. (2010). Religiosity as identity: toward an understanding of religion from a social identity perspective. *Personality and Social Psychology Review, 14*(1), 60 – 71.

10. Appendix

Table 1
Structural deviations of brain areas associated with OCD, schizophrenia, TLE, and mania compared to healthy controls

	Frontal lobes			
Area	OCD	Schizophrenia	TLE	Mania
Frontal lobes				Less white matter
Superior frontal gyrus	Less grey matter			
Middle frontal gyrus		R: Less white matter		
Inferior frontal gyrus	More grey matter			Less white matter
Medial frontal gyrus	Less grey matter	Less grey matter		
Prefrontal cortex		Less white matter		Less white matter
Dorsolateral prefrontal cortex	Less grey matter			
Orbitofrontal cortex	Less white matter	L: Less white matter		Less grey matter
Inferior frontal areas				Less grey matter
Precentral gyrus	R: Less grey matter	R: Increased grey matter density		
Paracentral lobule				Increased grey matter volume
	Temporal lobes			
Area	OCD	Schizophrenia	TLE	Mania
Temporal cortex		Less white matter		
Superior temporal gyrus			Less grey matter and white matter	R: Increased grey matter volume
Middle temporal gyrus	L: Less grey matter		Less grey matter and white matter	Increased grey matter volume and density
Inferior temporal gyrus		Less white matter	Less grey matter and white matter	
Fusiform gyrus			Less grey matter and white matter	L: Increased grey matter volume R: Increased grey matter density

Planum temporale		Less grey matter		
Insula		Less white matter	Less grey matter	
Anterior insula		Less grey matter		R: Less grey matter
Temporo-parieto-occipital area	R: Less grey matter			
		Parietal lobes		
Area	OCD	Schizophrenia	TLE	Mania
Parietal lobes	Less white matter			
Superior parietal gyrus				Increased grey matter density
Inferior parietal gyrus			L: Less grey matter	Increased grey matter density
Supramarginal gyrus	Less grey matter and white matter			
Precuneus		Less white matter		Increased grey matter density
		Occipital lobes		
Area	OCD	Schizophrenia	TLE	Mania
Lingual gyrus	L: Less white matter		L: Less white matter	
Cuneus		Less white matter		
		Limbic system		
Area	OCD	Schizophrenia	TLE	Mania
Amygdala			Increased and decreased volume	Less white matter (inconsistent)
Hippocampus			Decreased volume, less grey matter, less white matter	Less white matter (inconsistent)
Parahippocampal gyrus		Less white matter	Less white matter L: Less grey matter	
Cingulum	R: Less white matter		Less white matter R: Less grey matter	
Anterior cingulum		R: Less white matter		R: Less white matter

Anterior cingulate cortex	More grey matter, increased volume, less white matter	Less grey matter		Increased grey matter density
Posterior cingulate cortex	R: Less white matter			Increased grey matter volume and density
Isthmus				Decreased volume
Thalamus				Less white matter
Anterior thalamus		More white matter		
Posterior thalamus			Less white matter	
		Basal ganglia		
Area	OCD	Schizophrenia	TLE	Mania
Caudate nuclei			Less grey matter and white matter	Less grey matter
Putamen	More grey matter			Less grey matter
Globus pallidus	Decreased volume			
		Other subcortical areas		
Area	OCD	Schizophrenia	TLE	Mania
Corpus callosum	Less white matter		Less white matter	Decreased volume, less white matter
Anterior corpus callosum	Less white matter			Decreased volume
Posterior corpus callosum				Decreased volume
Anterior commissure				Less white matter
Internal capsule	Less white matter			Less white matter
Anterior limb of internal capsule	L: Less white matter		Less white matter	
Posterior part of external capsule		More white matter		
Nucleus accombens				Less grey matter
		Cerebellum		
Area	OCD	Schizophrenia	TLE	Mania
Cerebellum	L: Less grey matter		Less grey matter	Increased grey matter volume

	Brain stem			
Area	OCD	Schizophrenia	TLE	Mania
Pons	Less grey matter			
Mesencephalon/ midbrain	Less grey matter		R: less white matter	

	General			
Area	OCD	Schizophrenia	TLE	Mania
Cerebral cortex	White matter reduction		Volume loss	

Note. R=in the right hemisphere. L=in the left hemisphere.

Table 2
Activity deviations of brain areas associated with OCD, schizophrenia, TLE, and mania compared to healthy controls

	Frontal lobes			
Area	OCD	Schizophrenia	TLE	Mania
Frontal lobes		Increased activity	Ipsilateral increased activity	
Frontal cortex				L: Decreased activity
Dorsolateral prefrontal cortex	Decreased activity			
Orbitofrontal cortex	Increased activity		Increased activity	
Anterior orbitofrontal cortex	R: Increased activity			
Posterior orbitofrontal cortex	Increased activity			
Lateral frontal posterior area			L: Increased activity	
Inferior frontal cortex				Decreased activity
Medial frontal area				Decreased activity
	Temporal lobes			
Area	OCD	Schizophrenia	TLE	Mania
Temporal lobes		L: Increased activity	Ipsilateral increased activity	
Lateral temporal cortex			Increased activity	
Medial temporal lobe			Increased activity	Increased activity
Medial basal-temporal area				Decreased activity
	Parietal lobes			
Area	OCD	Schizophrenia	TLE	Mania
Parietal cortex	Increased activity			L: Decreased activity
Inferior parietal cortex	L: Increased activity			
Parieto-occipital cortex	L: increased activity			
	Occipital lobes			
Area	OCD	Schizophrenia	TLE	Mania
Occipital lobes		Decreased activity		Decreased activity

	Limbic system			
Area	OCD	Schizophrenia	TLE	Mania
Amygdala	L: Increased activity and decreased activity			Increased activity
Hippocampus				Increased activity
Parahippocampal gyrus		L: increased activity		Increased activity
Cingulate gyrus				Decreased activity
Anterior cingulate gyrus	Increased activity and L: decreased activity			L: decreased activity
Posterior cingulate gyrus	Increased activity	R: Decreased activity		
	Basal ganglia			
Area	OCD	Schizophrenia	TLE	Mania
Basal ganglia				Increased activity
Caudate nuclei head	Increased activity			
Putamen	L: Decreased activity			Decreased activity
Ventral striatum		L: Increased activity		
	Cerebellum			
Area	OCD	Schizophrenia	TLE	Mania
Cerebellum	R: Decreased activity			

Note. R=in the right hemisphere. L=in the left hemisphere.