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A case series study of the neurophysiological effects of altered states of mind during intense Islamic prayer

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ABSTRACT

This paper presents a case series with preliminary data regarding the neurophysiological effects of specific prayer practices associated with the Islamic religion. Such practices, like other prayer practices, are likely associated with several coordinated cognitive activities and a complex pattern of brain physiology. However, there may also be changes specific to the goals of Islamic prayer which has, as its most fundamental concept, the surrendering of one's self to God. To evaluate Islamic prayer practices, we measured changes in cerebral blood flow (CBF) using single photon emission computed tomography (SPECT) in three Islamic individuals while practicing two different types of Islamic prayer. In this case series, intense Islamic prayer practices generally showed decreased CBF in the prefrontal cortex and related frontal lobe structures, and the parietal lobes. However, there were also several regions that differed between the two types of prayer practices including increased CBF in the caudate nucleus, insula, thalamus, and globus pallidus. These patterns also appear distinct from concentrative techniques in which an individual focuses on a particular idea or object. It is hypothesized that the changes in brain activity may be associated with feelings of "surrender" and "connectedness with God" described to be experienced during these intense Islamic prayer practices. Overall, these results suggest that several coordinated cognitive processes occur during intense Islamic prayer. Methodological issues and implications of the results are also discussed.

1. Introduction

Prayer and meditation practices, in general, are complex neurocognitive tasks that are often associated with alterations in neurophysiological and psychological measures. There is a growing research base exploring the neurophysiological effects of secularized meditation practices (Davidson et al., 2003; Hölzel et al., 2011; Lazar et al., 2005; Newberg et al., 2001; Vago and Silbersweig, 2012). However, there are fewer studies exploring the relationship between the brain and specifically religious practices such as prayer. We previously published a pilot study on the brain scan findings in a group of Franciscan nuns performing a type of prayer called Centering prayer (Newberg et al., 2003). This type of prayer involves the purposeful focus on a particular prayer or phrase from the Bible. The results showed substantial increases in frontal lobe activity along with decreases in parietal lobe activity. We have also studied practices such as speaking in tongues (glossolalia) and mediumship (Newberg et al., 2006; Peres et al., 2012) which resulted in patterns of CBF that are both similar to and distinct from other practices. The purpose of this paper is to present the first ever case series of functional neuroimaging scans of intense Islamic prayer practices, and also consider some of the methodological challenges associated with such studies.

In this study, we present the 99mTc-HMPAO (hexamethyl propyleneamine oxime) SPECT data from three individuals performing intense Islamic prayer. Two of the subjects were American Sufis performing a practice called Dhikr (pronounced "zicker" with a soft 'z' and sometimes spelled Zhikr). This practice incorporates

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chanting, prayer, meditation, and various ritual movements with the overall purpose to remember and embrace the spirit of God. God, in the Islamic religion, embraces 99 qualities from kindness to rage and destruction to justice and peace. In Dhikr, in addition to the ritual elements, the individual reflects on the 99 qualities of God, to hopefully reach an intense spiritual experience in which the person deeply surrenders their self to God (or Allah). Indeed, the word "Islam" is often translated as "surrender" (Hood et al., 2009).

In contrast to the Sufi practice of Dhikr, Muslims perform prayers each day at specific times as specified in the Quran. These prayers, called salat, also invoke the 99 attributes of God and also help the person focus on surrendering to God and feeling God's love and compassion (Hood et al., 2009). These are among the essential elements of being a Muslim since they are performed on a daily basis throughout the person's lifetime. While the basis for performing these prayers comes from the religious doctrine found in the Quran, such practices will undoubtedly have a long lasting effect on brain function, and hence, psychological and cognitive processes. Part of the goal of evaluating the salat practice is to begin to understand the brain processes associated with such an important prayer practice.

In this paper, we also report the results from a scan of a single Islamic individual who performed salat in two different ways. Salat involves speaking the prayer out loud while going through a series of movement rituals involving standing, bowing, sitting, arm and hand movements, and prostration, while the person recites various verses and prayers. It takes between 10 and 20 min to complete. Like Dhikr, salat encourages the individual to remember and give thanks to God, and to surrender oneself to God's compassion and mercy. The individual in our study first performed the salat prayer in a more "automatic" manner. Thus, the elements of the prayer were performed with the goal of completing the prayer without necessarily striving for a more intense experience of surrender. The second time he performed the prayer more deliberately, specifically focusing on each element, and with the goal of striving for a deep sense of surrender.

Since one of the goals of this paper is to consider methodological issues with regard to the study of religious and spiritual practices and experiences, it is worth noting here that the very attempt at performing practices in different ways or with different intensities is particularly difficult to evaluate scientifically. The intensity of these experiences is completely subjective. As a researcher, we can only rely on the subjective report of the individual with regard to the intensity or the subjective elements of the experience. Thus, if an individual states that he had an intense feeling of surrendering to God, other than comparing to our own personal experiences, we as researchers cannot definitively quantify that subjective component of the experience. On the other hand, this issue lies at the heart of methodological concerns regarding many psychological states such as depression or anxiety. Although we can all relate to these feelings, we can never know for certain what another individual feels, especially when placed into a scanning environment. However, we must rely on individual reports while comparing findings on brain scans to those subjective reports, as we describe in the current paper.

With the availability of functional imaging techniques such as positron emission tomography (PET), single photon emission computed tomography (SPECT), and functional magnetic resonance imaging (fMRI), there has been a growing number of studies utilizing such techniques to evaluate brain function in meditative and spiritual practices. Each of these imaging modalities, in additional to other neurophysiological measures such as electroencephalography, have advantages and disadvantages for studying such practices (for a review, see Newberg, 2010 and Newberg and Lee, 2005).

We also would like to emphasize that we chose SPECT imaging and the methodology described below over other imaging techniques for several important practical reasons. The major reason for the choice of SPECT is that the subject can be injected with the tracer through an intravenous catheter thus allowing the person relatively free range of movement with both the hands and the body. Since the tracer is rapidly taken up in the brain (i.e. 2–3 min) and does not significantly redistribute once it has entered the neuron, an individual can be injected during a particular practice or state so that the CBF measurement reflects the brain function during that state. For example, we injected the subjects described in this paper during their Islamic prayer practice (with approximately 5 min left in the practice) which allowed for an assessment of CBF during the last, and theoretically deepest, stage of the prayer. Once the practice is completed and the subject brought into the scanner, the images obtained still reflect the CBF pattern at the time of tracer injection.

Functional magnetic resonance imaging (fMRI) has substantially better spatial resolution over SPECT, and the ability to immediately correlate functional with anatomic images. However, fMRI would be very difficult to utilize for the study of Islamic prayer practices since these include specific and considerable movements of the body and hands throughout the entire practice. There would be no way to adequately do these practices in the fMRI scanning environment. The growing number of fMRI studies of meditation practices demonstrates that fMRI has an important application in the study of such practices, but only when these practices can be adequately performed while lying in the scanner. PET imaging also provides better spatial resolution than SPECT and could theoretically be injected during the prayer practice since it too does not significantly redistribute. However, the uptake of F-18 fluorodeoxyglucose, the current PET tracer for brain imaging, requires approximately 25–30 min for its uptake which is problematic for the study of specific states associated with prayer practices. Thus, while PET and fMRI offer certain technical advantages, SPECT appeared to provide the best option for this initial study of Islamic prayer (see Fig. 1).

With regard to specific areas of the brain that might be involved during prayer, and particularly Islamic prayer, we have elaborated several hypotheses for this study that were based, in part, upon the results of our previous research, as well as others, on religious and spiritual practices. Importantly, we acknowledge that many of the brain processes associated with prayer practices are likely to be associated with well-known brain networks that support how the individual might be psychologically oriented towards God in terms of the relationship and also the emotional content (Kapogiannis et al., 2009). Thus, different types of prayer appear to be associated with the activation of specific brain regions related to processes underlying social interactions or positive emotions (Schjodt et al., 2008, 2009). Given these studies along with our previous findings, we hypothesized the following: (1) decreased activation of the frontal regions during intense Islamic prayer, including the prefrontal cortex. Several investigators, including our group, have observed increased activity in the frontal lobes, and in particular the prefrontal cortex, during concentrative tasks including meditation practices (Herzog et al., 1990–1991; Lou et al., 1999; Newberg et al., 2001; Pardo et al., 1991). However, in practices in which a principle component of the experience is the sense of surrender such as in glossolalia, we found decreased activity in the frontal regions, particularly the prefrontal cortex (Newberg et al., 2006; Peres et al., 2012). In the present study, we predicted that we would find the latter, surrender-type activation pattern. (2) Decreased activation of the parietal lobe structures. Our previous research has shown that meditative prayer, such as Centering prayer, is associated with alterations in the subjective experience of space, particularly a sense of spacelessness or oneness (Newberg et al., 2001, 2003). (3) Decreased activation of the primary sensory areas and visual cortex. This hypothesis was informed by research demonstrating that meditation and prayer subjects often describe decreased sensory awareness (Farb et al., 2013; Zeidan et al., 2011; Kakigi et al., 2005).

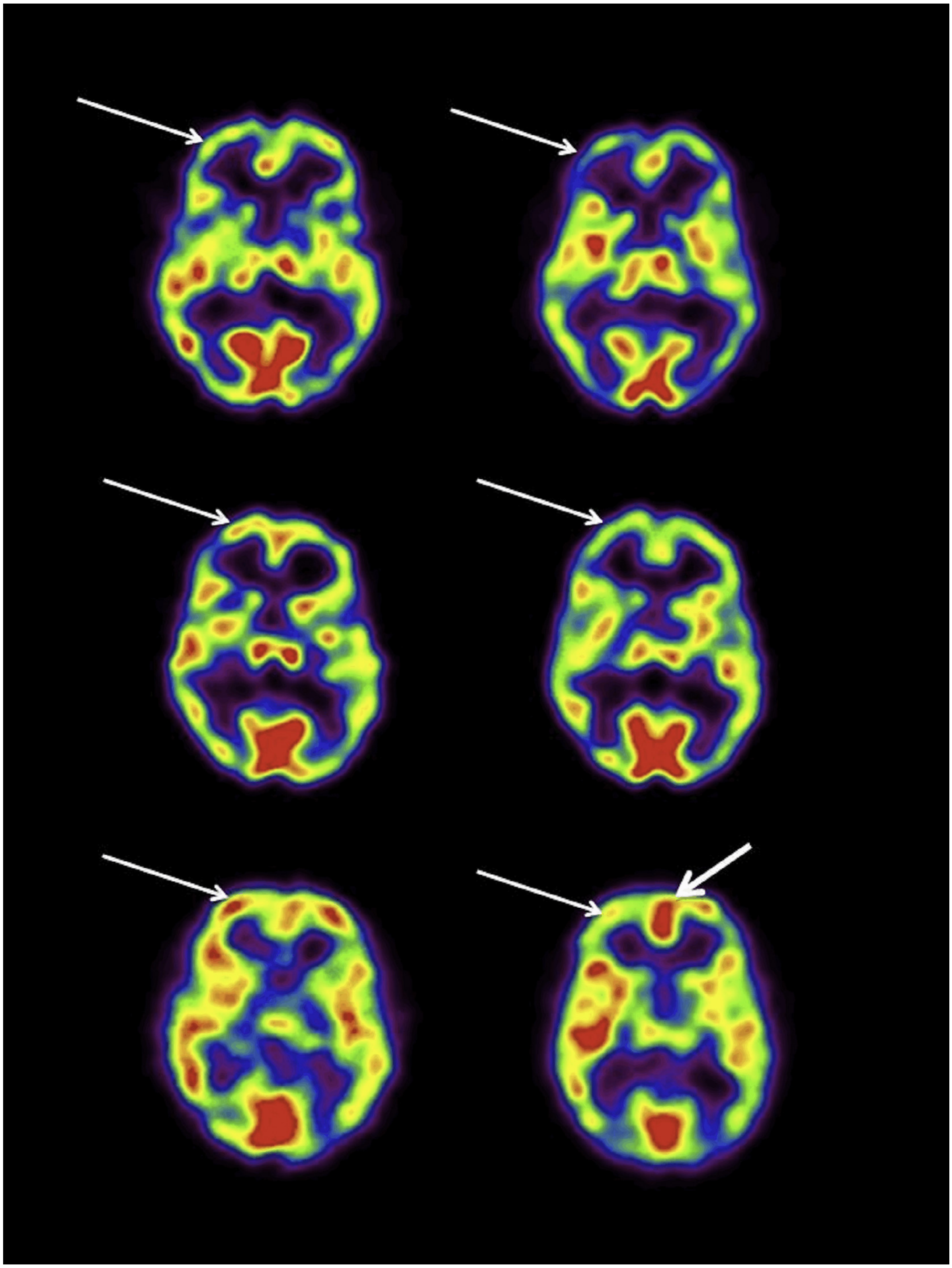

Fig. 1. Transaxial SPECT scan results from each of the participants performing intense Islamic prayer practices (CBF ranges from high to low as demonstrated by the colors red > yellow > green > blue > black). The scans in the left column show the resting scan in the first two Sufi practitioners (first two rows) and the automatic salat practice of the third subject. The scans in the right column show the CBF pattern during intense Islamic prayer for the Dhikr in the two Sufi practitioners and the more intense form of salat in the third individual. The scans demonstrate general decreased frontal lobe activity (thin arrow) in all three participants during intense prayer. The individual performing salat also showed increased activity in the anterior cingulate gyrus (thick arrow).

2. Methods

2.1. Subjects and imaging acquisition

We present the scan results of three Islamic individuals as a case series. Each subject was well practiced in Islamic prayer and actively performed their practice on a daily basis for more than fifteen years. Two subjects were practicing American Sufi's (one female and one male) who performed their prayer practice on a daily basis. In particular, they performed the prayer called Dhikr which was described above. The other subject was Muslim and performed Islamic prayer on a daily basis. None of the subjects had any history or clinical evidence of medical or neuropsychological problems, and had no history of alcohol or drug abuse that would potentially alter cerebral blood flow. The methods for this study were similar to those described in our previous studies of meditation and prayer practices (Newberg et al., 2001, 2003, 2006).

On the day of the study, after obtaining informed consent (approved by the human Institutional Review Board with the study protocol), a hospital room was set up to function as a meditation room ensuring a quiet, comfortable environment in which to practice the prayer. Approximately 20 min prior to the baseline scan, an intravenous cannula (IV) was placed in one arm. The subjects reported minimal discomfort from the IV that resolved prior to initiating the remainder of the study. The two Sufi subjects were instructed to rest in the room with their eyes closed and ears unoccluded for 5–10 min at which time they were injected through the IV with the initial dose of ^{99m}TC-HMPAO (Amersham International, Arlington Heights, IL, prepared as specified by the manufacturer). Thirty minutes following the injection, the subject was scanned for 45 min. For the salat practitioner, the only difference is that his initial scan was while performing salat more "automatically". He was injected with the initial dose of the tracer approximately 5 min prior to the conclusion of the prayer practice.

Following this initial scan, the subjects returned to the room for their intensive prayer session (for the Sufis, this was the Dhikr practice, and for the other subject, he performed salat with greater intensity). The subjects were allowed to utilize the Quran initially and perform the various ritual movements and other components of the prayer. They each had their eyes closed (their ears were also unoccluded) during approximately the final 10 min of the prayer session, including during the time of the second injection of the HMPAO (this was the same as the method used for our prior studies). Outside noise was kept to a minimum and the door of the room was closed during the initial and intense prayer scans. The prayer session was ended and thirty minutes after this injection the subject was scanned for 30 min using the same imaging parameters as for the baseline study.

The SPECT images were reconstructed in the transaxial, coronal, and sagittal planes using filtered backprojection, followed by a Wiener post filter and 1st order Chang attenuation correction. The reconstructed slice thickness was 4 mm with a spatial resolution of 8–10 mm.

2.2. Image analysis

The images of the initial state and intense prayer scans were reconstructed and resliced, using an oblique reformatting program, according to the anterior-posterior commissure line so that the final two sets were at comparable anatomical sites for the analysis. A previously validated template methodology consisting of regions of interest (ROIs) corresponding to the major cortical and subcortical structures was placed over the baseline scan (Resnick et al., 1993; Newberg et al., 2005). For the purposes of this study, we examined the rCBF as measured in selected ROIs which were hypothesis driven. The ROIs examined are given in Table 1 and include the inferior frontal, superior frontal, prefrontal, orbitofrontal, dorsal medial cortex, inferior temporal, superior parietal, inferior parietal, occipital, and sensory strip, as well as the caudate, thalami, cerebellum, and cingulate gyrus. Each ROI (which are small and therefore represents a "punch biopsy" of any given area) had its placement adjusted manually in order to achieve the best fit according to the atlas. The ROIs were then copied directly onto the second scan. This was possible because the images were already resliced into the same planes as described above. The count values for the intense prayer scans were obtained by determining the number of counts in each ROI on the prayer scan and subtracting the number of counts in the same ROI from the initial scan which were decay corrected to the midpoint of the two scans. Counts per pixel in each ROI were obtained for both the initial and intense prayer scans and normalized to the whole brain activity. This provides an rCBF ratio for each ROI compared to the whole brain. A percentage change was calculated using the equation:

$$\% \text{ Change} = \frac{(\text{Prayer} - \text{Initial})}{\text{Initial}} \times 100$$

Since this is a case series, no statistical analyses were utilized. The data are presented as the difference between the intense prayer scan and the initial scan. Positive results indicate increased CBF in a given ROI and a negative result indicates decreased CBF.

Table 1
Percentage change between the first scan and second scan.

Region name	Sufi #1	Sufi #2	Salat
	Change	Change	Change
Rt. Anterior cingulate	−4.5	−8.8	10.3
Lt. Anterior cingulate	−4.9	−13.0	7.4
Rt. Dorsal medial cortex	−0.3	−6.7	7.3
Lt. Dorsal medial cortex	−6.9	−13.1	2.9
Rt. Prefrontal cortex	−6.7	−9.7	−5.8
Lt. Prefrontal cortex	−11.6	−0.8	0.8
Rt. Inferior frontal lobe	−14.2	−6.0	−7.5
Lt. Inferior frontal lobe	−8.1	−11.8	1.4
Lt. Orbital front cortex	−9.4	−7.2	−25.1
Rt. Orbital frontal cortex	−14.0	−26.7	−41.2
Rt. Superior frontal lobe	−15.7	−6.8	−4.9
Lt. Superior frontal lobe	−15.1	−5.9	0.8
Rt. Sensory strip	−4.1	−2.6	−0.9
Lt. Sensory strip	−5.1	−8.2	−12.3
Rt. Superior Temporal Lobe	−25.9	−6.1	−2.2
Lt. Superior temporal lobe	−7.8	−4.4	0.6
Rt. Inferior temporal lobe	−2.8	−21.2	1.7
Lt. Inferior temporal lobe	−31.2	−11.0	−2.5
Rt. Parietal lobe	−10.8	−4.2	−6.1
Lt. Parietal lobe	−6.1	−6.9	−5.5
Rt. Precuneus	−11.2	−7.2	−15.4
Lt. Precuneus	−4.0	−12.0	−8.8
Rt. Superior parietal lobe	−9.6	−33.3	−11.9
Lt. Superior parietal lobe	−5.4	−5.2	−12.5
Rt. Angular gyrus	−18.4	−9.4	−8.5
Lt. Angular gyrus	−8.5	−5.5	5.9
Rt. Lateral visual cortex	−20.9	−7.2	−18.0
Lt. Lateral visual cortex	−19.2	−1.0	−13.5
Rt. Calcarine cortex	−12.4	−18.0	−21.2
Lt. Calcarine cortex	−10.8	−19.0	−4.8
Rt. Medial occipital lobe	−4.3	−15.1	−9.5
Lt. Medial occipital lobe	−8.3	−18.3	−3.8
Rt. Caudate	−21.2	−3.4	16.0
Lt. Caudate	−4.5	−12.5	31.1
Rt. Insula	2.2	−2.3	11.7
Lt. Insula	−16.3	−2.1	14.2
Rt. Thalamus	0.0	−6.5	18.8
Lt. Thalamus	1.6	−1.4	9.5
Rt. Globus pallidus	−15.6	−4.3	15.4
Lt. Globus pallidus	−12.1	−14.9	40.3
Rt. Hippocampus	−1.4	−6.7	−19.2
Lt. Hippocampus	−10.2	−7.2	−3.5
Rt. Amygdala	−0.1	−4.5	−1.2
Lt. Amygdala	−45.6	−1.0	4.2
Rt. Cerebellum	−5.7	−5.9	−1.9
Lt. Cerebellum	−2.7	−3.9	−0.2
Rt. Cingulate body	0.1	−10.1	7.5
Lt. Cingulate body	−4.2	−11.7	−8.1

"-" result implies that this region had decreased blood flow on the second scan. In the two Sufi practitioners, the change is between the Dhikr practice and resting baseline. In the salat prayer, the change is between the "automatic" prayer and the deeper, more intense, prayer.

3. Results

The results showed predicted change in the pattern of activity between the prayer and initial scans (Fig. 1, Table 1). For the most part, decreased CBF was observed in a variety of frontal, temporal, and parietal lobe regions in both types of Islamic prayer.

Interestingly, in the intense salat prayer, there were also activations in the anterior cingulate, dorsal medial cortex, caudate, insula, thalamus, and globus pallidus. These areas generally showed decreases in activity in these same regions during the Sufi Dhikr practice. All participants reported that during the practice, they had intense experiences of surrender and connectedness to God. In particular, the individual performing the salat practice in two different ways reported that the intense form resulted in an increased sense of surrender and connectedness to God, something that was perceived only mildly when the practice was performed in a more automatic manner.

4. Discussion

Our results reveal some intriguing issues related to prayer in general, Islamic prayer in particular, and the overall field of research using functional neuroimaging to study religious and spiritual practices. In this case series we explored the effects of intense Islamic prayer on brain function. Sufis employ a variety of techniques for achieving the experience of "mystical union with the divine." The practice, Dhikr, has as its purpose to remember and embrace the spirit of God. It is a prayer that is performed by many Muslims, but it can be particularly powerful when performed by a "mystic" due to the experience and intensity of practice usually associated with this lauded and colloquial category of an advanced Sufi practitioner. The second type of prayer we studied was salat, a repetitive recitation which is practiced by Muslims five times a day. As with many prayer practices, salat can be performed in a more automatic manner, or in a deeper manner in which a person strives for that deep experience of surrender and connection to God. This difference in performance bears similarities to Allport's (1950) distinction between intrinsic (self-motivated) and extrinsic (socially-motivated) forms of religious commitment.

The present study of Islamic prayer, in spite of the limited sample size, addressed each of our initial hypotheses. The first hypothesis, that these prayer practices would reduce activity in the prefrontal cortex along with other frontal lobe structures, was supported by the results. The decreased frontal activity is also consistent with imaging studies of other practices such as glossolalia (speaking in tongues) and mediumistic practices (Newberg et al., 2006; Peres et al., 2012). In all of these practices, the person experiences a sense of surrender and lack of personal, willful control. This can be experienced either explicitly, as in the case of Islam, or implicitly as when a medium feels taken over by the spirits. These findings also contrast with those from studies of other practices and tasks in which the individual focuses on an object, word, concept, or sacred phrase. This intense willful focus or concentration is typically associated with increased activity in the prefrontal cortex (Frith et al., 1991; Pardo et al., 1991). The increased PFC activity observed during the concentrative practices such as Centering prayer or Buddhist meditation is most likely related to the active process of meditation in which subjects willfully concentrate upon their meditation. However, there are also practices in each religious tradition which are associated with a feeling of surrender, in a manner similar to that observed with Islamic prayer. As mentioned above, Christians who speak in tongues feel a sense of surrender to the Holy Spirit that enables the practice to occur. Thus, an important question for future investigation is whether it is the religious tradition itself or the elements of a particular practice that elicit specific patterns of brain activity.

An additional interesting distinction observed during the salat prayer was an increase in the anterior cingulate gyrus activity. Decreased anterior cingulate activity was observed in the Sufi practice of Dhikr. In our other studies of attention focusing practices, we have typically observed concomitant increases of anterior cingulate activity along with increased activity in the prefrontal cortex. It is unclear whether such a finding reflects a distinct brain state associated with intense salat prayer or whether this is just an artifact related to the individual scan. However, if this is a true finding, it could have some interesting implications for understanding the relationship between the prefrontal cortex and anterior cingulate during these intense prayer practices and also for understanding how such practices may affect psychological status. The anterior cingulate is involved with emotional regulation, learning, and memory, and plays a major role in lowering anxiety and irritability, and enhancing emotional and social awareness (Gu et al., 2013; Langguth et al., 2007; Fincham and Anderson, 2006).

Our second hypothesis was that Islamic prayer practices would involve a decrease in the activity in the superior parietal areas. These parietal regions are generally associated with the sense of an altered experience of space during prayer (d'Aquili and Newberg, 1993). Indeed, both the Dhikr and salat prayer practices were associated with decreased CBF in the parietal regions, including the superior parietal area. Several studies have shown that there are alterations in activity in the superior parietal lobe, particularly in association with increased activity in the prefrontal cortex, in subjects performing visual-spatial tasks (Cohen et al., 1996; D'Esposito et al., 1998). Thus, these studies not only suggest that the superior parietal lobe is associated with spatial processing, but that it interacts with the PFC during such processing.

Decreased CBF was also observed in the temporal lobe regions during the Dhikr prayer, but not so much in the salat prayer. This could be relevant as the temporal regions have frequently been implicated as an area involved in religious and spiritual experiences (Cook and Persinger, 1997).

Our third hypothesis suggested that there would be decreased activity in sensory areas of the brain. This was generally shown in all three subjects with decreased CBF during intense Dhikr and salat prayer in the sensorimotor area and visual cortical regions. This decrease might be associated with the experience of reduced sensory input reported by practitioners.

Additionally, it should be noted that specific changes were observed in the default mode network (DMN) structures such as the temporal lobe, prefrontal cortex, posterior cingulate cortex, along with the precuneus and the inferior parietal cortex (Zhang and Li, 2012; Buckner et al., 2008). In our case series, the Islamic practices generally resulted in decreased activity in these structures. Similarly, there is reduced activation and reduced functional connectivity of the DMN in long-term practitioners of various meditation practices (Fox et al., 2014). Since the DMN is defined as the brain network that decreases during a cognitive task, the decreased activity in the DMN during Islamic prayer indicates that it is a real neurocognitive task, as opposed to mere mind-wandering.

It is also important to try to understand the reason for the underlying brain changes associated with Islamic prayer and clarify the similarities and differences with other types of prayer. As we described above, some of the current findings reveal similarities and differences compared to other practices our group has studied. The decreased frontal lobe activity is similar to that observed in individuals performing the Pentecostal practice of speaking in tongues (Newberg et al., 2006) and distinct from attention focusing practices such as Tibetan Buddist or Kirtan Kriya meditation (Newberg et al., 2001; Wang et al., 2011). Several other studies are worth mentioning in this regard. For example, Schjodt et al. (2009) used fMRI to find differences in brain activity patterns when performing a formalized repetitive prayer versus a more improvised form of prayer in a group of Christians. This study reported that improvised prayer activated a strong response in the temporopolar region, the medial prefrontal cortex, the temporo-parietal junction and precuneus. The notion that a personal prayer, which is approached in a manner similar to "normal" interpersonal interactions activates brain areas related to social engagement and cognition. The Islamic practices studied in this case series differ with regard to prayers that are more improvised and conversational, both in terms of the specific prayer elements and in terms of the brain related changes. For this reason, we may have observed the different patterns of brain activity compared to those other types of prayer.

During the intense salat prayer, we observed increased activity in the reward network structures such as the caudate. Schjodt et al. (2008) reported a similar significant increase in activity in the caudate nucleus in a group of Christians during praying that resulted in highly positive emotional experiences. This was observed more in the current study with the intense practice rather than the more "automatic" practice that did not elicit the same degree of positive emotions.

Of course, it is important to emphasize whether the similarities and differences in brain activity patterns across different prayer practices are related to the elements of the prayer itself or related to the elements of the religious belief system from which they derive. For instance, Kapogiannis et al. (2009) proposed an integrative cognitive neuroscience framework for understanding the cognitive and neural foundations of religious beliefs based upon three psychological dimensions – God's perceived level of involvement, God's perceived emotional relationship, and doctrinal/experiential religious knowledge. These authors further argued that brain networks underlying specific psychological Theory of Mind processes such as intent and emotion, abstract semantics, and imagery underlie related religious constructs as well. In this way, religious beliefs may be related to brain processes that are used for other cognitive functions that can also have evolutionary adaptive advantages (d'Aquili and Newberg, 1999). Future studies with larger numbers of subjects from many different religious traditions performing many different practices will be necessary to delineate the impact of religious belief, religious practices, and religious experiences on the brain.

While not the explicit focus of the current paper, it should be mentioned that studies such as these may ultimately help establish any potentially therapeutic benefits of meditation and prayer practices. Several studies have found benefits from doing a daily meditation practice (Goyal et al., 2014). For example, a recent study showed that Muslims who performed daily salat maintained increased balance (an important physiological function, especially for elders) compared to a similar sample of non-practicing Muslims (Alabdulwahab et al., 2013). In another study conducted at an Iranian university, forty-five minutes of Islamic prayer significantly reduced anxiety for Muslims who were about to go into surgery (Hosseini et al., 2013). Thus, imaging studies can be useful in delineating: (1) the neurophysiological mechanism of action of these practices, (2) how neurophysiological changes correlate with the subjective experience of these practices, and (3) how such practices might lead to improvements in psychological states.

We present this case series study to illustrate several points regarding the measurement of cerebral blood flow during intense Islamic prayer practices. We have shown a simple method by which SPECT can be used in order to detect changes in rCBF during intense prayer practices. Also, this methodology should be applicable to a variety of religious and spiritual practices in order to explore how different practices are associated with different neurophysiological correlates.

As mentioned, there are many challenges to performing functional neuroimaging studies of intense prayer or meditation practices. The primary challenge is the fact that the subjective experience of the practice is difficult to measure. Although a variety of questionnaires may be used to assess religious or spiritual experiences, these are not useful in the acute setting since a person cannot be asked questions in the moment, and what the person experiences at the time of the scanning (or injection) could be different from what they report after the fact. In spite of this limitation, it is important to assess subjective experiences either qualitatively or quantitatively. In this study, all participants in our case series subjectively reported to the investigators that they had had an intense prayer session. This study also measured cerebral blood flow at a single point during a lengthy prayer practice during which a number of different cognitive and affective processes likely occurred. Thus, the images were taken only during the assumed "peak" of prayer, and may, in fact, reflect activity during some other component of the prayer practice. Finally, this preliminary case series has a limited number of subjects since it is often difficult to find highly experienced practitioners willing to undergo scanning while performing their spiritual practice in a laboratory setting. This limited number of subjects makes any definitive conclusions from the current data impossible. Furthermore, since we did not have a control group, it further complicates the ability to determine what specific elements of the prayer practice may have actually been related to the brain changes. It is not clear whether the changes observed may have been related to the underlying belief system of Islam, the specific movements of the prayer, the phrases recited, or the actual experience of the individual. Each of these elements by themselves, or in conjunction, may or may not have contributed to the changes in brain function that were observed. However, with this preliminary data, it is hoped that future studies can address the limitation of the current study by using a more rigorous methodology to explore the psychological and neurophysiological impact of intense prayer practices in Islam, as well as those from other religious and spiritual traditions.

5. Conclusion

The results from this case series have begun to assess the neurophysiological correlates of the complex neurocognitive task of intense Islamic prayer practices. The findings support our hypotheses that these intense prayer practices, especially when accompanied with an experience of surrender, are associated with decreased activity in the frontal regions. In addition, the decrease of activity in the parietal regions may be associated with the subjective experience of spacelessness and a feeling of being connected to, or one with, God. Future imaging research should explore the cerebral correlates of intense prayer practices in a larger number of subjects as well as incorporate other psychometric, physiological, and neurophysiological measures. Such studies will be essential to elucidate the basic mechanisms that underlie subjective and clinical observations during the complex neurocognitive task of intense prayer practices.

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