

Author's Statement

The goal of this assignment was to conduct an in-depth review of the empirical literature on a neuroscience topic of our choosing. We were tasked with choosing a topic and finding several studies that answered the research question we posed, then compiling our findings into an APA style literature review. I wanted to answer the question, "What brain regions are activated during prayer?" I did not want to limit my examination of prayer to a specific prayer type or religious group, so I hoped to include as many forms as prayer as I could find represented in the existing research. My inquiry fell within a specific subfield of neuroscience called Neurotheology.

A Comprehensive Review of Prayer and Its Neural Correlates

Abstract

Spirituality has been important within human civilization for thousands of years. The field of neurotheology explores the unique relationship between spirituality and the brain. Many reviews exist on secular meditation and the neurotheology field in general, but the neural activations connected to prayer are not yet fully understood. This review examines the neural correlates of various prayer types within different religious groups. A systematic literature search was performed in PubMed and Google Scholar for empirical studies on prayer utilizing brain imaging. Islam, Christianity, and Buddhism were represented in the seven articles found, and conversational, verbal mantra, visualization, and specific Islamic prayer practices were examined. Theory of Mind regions were activated during Christian conversational prayer, suggesting this type of prayer is processed as interpersonal interaction; decreased activity was connected to Islamic Salat and Dikhr prayer. Frontal lobe activations connected to cognitive control functions occurred during conversational and meditative prayer by Christians and Buddhists but decreased during Islamic prayer. Buddhist verbal prayer, visualization prayer, and repetitive Salat prayer led to cingulate cortex activations related to attention-focusing. Parietal lobe activity, connected to an altered spatial awareness, only increased during Christian conversational prayer. Brain activations varied for each prayer type and denomination, suggesting that there is not one universal neural correlate for either variable. Further research is needed to determine how the physical mechanisms of prayer versus the goal of each prayer practice may influence brain activations. A more diverse representation of faiths in empirical research is also needed to provide intersectional analysis.

A Comprehensive Review of Prayer and its Neural Correlates

Religion and spirituality have been prominent in human civilization for almost 500,000

years (Koenig, 2009). Religion binds people together, serving as a common principle that guides connection, as well as having a significant impact on decision-making, social norms, and politics. Religion can be broadly defined as a set of beliefs and practices that, through rituals, aim to connect to or reckon with a mystical higher power or the oneness of the universe (Froese & Jones, 2020). Today, religious practices can be found in 90% of the world (Koenig, 2009); a 2012 poll indicated that 74% of religiously affiliated individuals identify with Buddhism, Hinduism, Christianity, Islam, or Judaism (Adams et al., 2016). However, the study of psychology and science in general has become secularized since the 20th century (Rim et al., 2019).

Neurotheology is an emerging interdisciplinary field that seeks to examine the intersection of spirituality and the brain. The field can be defined as an exploration of the neurological underpinnings behind religious experiences in addition to biological predictors of religiosity (Sayadmansour, 2014). This study aims to address the first facet— the neural correlates actively engaged in isolated spiritual moments— as opposed to the abstracted relationship between theology and neurobiology.

In the field of neurotheology, there are two prominent schools of thought— reductionist, a conception of religious experience as a neurological accident, and religionist, a conception of neural activation as the aftermath of a valid religious phenomenon (Shukla et al., 2013). My aim is not to affirm either, but to provide an objective review of empirical evidence on the neural correlates of a specific religious activity— prayer.

Prayer

Prayer can be defined as a ritual practiced individually or collectively to transcendently connect with the divine realm (Froese & Jones, 2020). Prayer may be an unstructured conversation with God, benedictions (blessings), sung hymns, ceremonial prayers, statements of

praise, or repetitive statements (Hamman, n.d.). Prayer practices vary greatly across different religions, with some religions like Islam containing daily structured prayers, and others like Protestant Christianity including more casual conversational prayer practices (Hamman, n.d.).

Prayer is often described as “healing” by those who engage in it, which has been corroborated by previous studies. Frequent prayer is correlated with some improvement in physical health and mental well-being over time (Andrade, 2009). This review aims to examine the various neural correlates of prayer while taking into account different religious affiliations and practices. An enhanced understanding of the correlation between neural activity and prayer may inform the use of prayer as a possible tool for personal healing. In addition, many religious groups have historically been in contention; despite ideological differences, commonalities may exist in the impact of diverse prayer practices. Understanding the similarities and differences in the neuroscience behind and benefits of various forms of prayer can help us better understand our peers of different faiths and respect their practices.

The Association Between Prayer and Meditation

Prayer may be conceptualized as a specific subset of meditation; meditation may be used in a secular sense to describe modern mindfulness practices, including body scans, yoga, breath regulation, loving-kindness affirmations, and transcendental mantra meditation (Dooley, 2009). Many empirical studies have studied meditation, which has been associated with a return to neurological and physical homeostasis; meditation has implications for neuroplasticity and calming neural processes like cortisol responses (Dooley, 2009). Prior reviews have examined the neural correlates of secular meditation, but few have examined religious meditative practices (Dooley, 2009). Both mindfulness and prayer may be informed by goals of self-reflection, support during times of stress, control, and a positive emotional outlook. For the purpose of this review, prayer will be differentiated from broader meditation practices by identifying the goal of divine connection or a specific spiritual purpose. This review can expand prior reviews on

secular meditation (Hanson, 2021) and our understanding of its impact by specifically looking at the neural correlates of meditative experiences informed by religious goals. **Methods**

PubMed was used to look for empirical studies. A separate search was performed on a broader database, Google Scholar, to find studies specific to underrepresented religious affiliations like Islam and Buddhism. The search terms (neur*) OR (brain) AND (prayer) were used, using NOT (psilocybin) and NOT (yoga) to pare out studies that did not look at religious participants. These search terms yielded 595 results. Google Scholar generated thousands of results with dwindling relevancy after the first 10. The criteria for inclusion was that the studies focused on collecting data to identify brain regions, using either EEG or brain imaging. In addition, the studies had to look specifically at prayer, but there was flexibility on denomination and method. Theoretical assessments of the neurobiology field, which largely comprised the results, were excluded.

Results

Methodical Variation

Seven articles met the criteria for inclusion (Schdoejt et al., 2009; Barcelona et al., 2020; Newberg et al., 2001; Neubauer, 2013; Newberg et al., 2015; Newberg et al., 2003; Gao et al., 2017). There was a dearth of sources on Jewish prayer and Hindu prayer, but empirical studies on Christian, Muslim, and Buddhist prayer were found. Christian denominations represented included Catholic (Barcelona et al., 2020; Newberg et al., 2003), Lutheran (Schdoejt et al., 2009), and Pentecostal (Neubauer, 2013). Sikh and Dikhir prayer within the Muslim faith was represented (Newberg et al., 2015), as well as two forms of Buddhist prayer (Newberg et al., 2001; Gao et al., 2017).

Various forms of prayer were represented among the different religious affiliations. Repetitive verbal prayer, or mantra prayer, was performed by Catholic participants (Barcelona et

al., 2020; Newberg et al., 2003), Lutheran participants (Schdoejt et al., 2009), and Buddhist participants (Gao et al., 2017). Visualization meditation was also performed by Buddhist participants (Newberg et al., 2001). Conversational prayer was examined in Lutheran (Schdoejt et al., 2009) and Pentecostal Christians (Neubauer et al., 2013). Specific, structured Islamic prayer practices that combine movement, verbal components, and internal prayer were also examined (Newberg et al., 2015). Some required 15+ years of prayer experience for entry into the study (Newberg et al., 2001, Newberg et al., 2003) whereas others required less experience (Neubauer et al., 2013, Gao et al., 2017). The age demographics for each study varied greatly, with one notable study of exclusively elderly women (Barcelona et al., 2020) and another of exclusively young to middle-aged participants (Schdoejt et al., 2009).

The methods for brain imaging included Electroencephalogram (EEG) recordings, which rely on sensors to pick up electrical signals in the brain (Barcelona et al., 2020; Gao et al., 2017). Functional magnetic resonance imaging (fMRI), which measures blood flow in the brain (Neubauer, 2001; Schdoejt et al., 2009), and single photon emission computerized technology (SPECT), a nuclear imaging mechanism, were also used (Newberg et al., 2001; Newberg et al., 2015; Newberg et al., 2003). Some studies imposed non-religious conditions to compare with religious states (Neubauer et al., 2013; Gao et al., 2017), whereas others took measurements before, during, and after uninterrupted prayer sessions (Newberg et al., 2015; Newberg et al., 2001; Newberg et al., 2003).

Major Findings

Theory of Mind Network

Similar brain regions were highlighted during conversational prayer. Lutheran Christian subjects activated brain regions associated with social cognition during improvised prayer, including the prefrontal cortex, precuneus, and temporoparietal junction (Schdoejt et al., 2009). These regions are associated with the Theory of Mind network, which is related to processing the

mental states of oneself and others during reciprocal social interactions (Schdоеjt et al., 2009). The prefrontal cortex and temporoparietal junction are the core regions of the network, which extends to the precuneus, amygdala, anterior and posterior cingulate cortex, and more (Lizcano-Cortés et al., 2021). Similarly, the medial prefrontal cortex, posterior cingulate cortex, and parietal lobe near the temporoparietal junction were engaged when Pentecostal Christians engaged in conversational prayer (Neubauer, 2013). The activation of Theory of Mind network regions suggests that personal prayer with God is processed as interpersonal interaction, but these results are not generalizable as these studies examined only Christian conversational prayer.

Conversational prayer is practiced to build a relationship with God, whereas the Islamic Salat and Dikhr prayers are practiced with the goal of surrendering to the divine (Newberg et al., 2015). Salat and Dikhr prayer were correlated with decreased activity in the Theory of Mind network (Newberg et al., 2015). Both Islam and Christianity are monotheistic religions, but the goals and mechanisms of the prayers examined differ. Salat prayer consists of verbal repetition of a mantra, whereas Dikhr prayer combines verbal mantra, internal recitation, and movement (Newberg et al., 2015). Further research is needed to determine how the goal of prayer versus the psychological mechanisms of performing the prayer impact the brain regions activated.

Frontal Lobe Activations

There were similarities and differences in the brain regions highlighted for other forms of Christian prayer. Catholic participants performing internal mantra prayer showed brain activations in the frontal lobe (Barcelona et al., 2020). The prefrontal cortex was activated when Catholic participants performed verbal mantra prayer (Newberg et al., 2003), and was activated during conversational prayer in other studies on Christians (Newberg et al., 2015; Neubauer, 2013). However, these brain regions were not exclusively activated during Christian prayer. The prefrontal cortex was also engaged when Buddhist participants performed visualization prayer (Newberg et al., 2001).

In addition to being implicated in social behavior, the prefrontal cortex is involved in cognitive control functions (Newberg et al., 2015). Prefrontal cortex activation during meditation in anxiety disorder patients was correlated with improved mental health (Hözel et al., 2013). These forms of prayer may have positive implications for our wellbeing, a commonality that exists despite any ideological or mechanical differences in prayer types.

Prefrontal cortex activity was decreased during salat and Dikhr prayer, which are not attention-focusing prayer practices (Newberg et al., 2015). Prefrontal cortex activity was also decreased when Christians spoke in tongues, a phenomenon that reflects submission to the holy spirit (Newberg et al., 2006). The degree to which attention is focused during prayer (which varies based on prayer type) may be a predictor of prefrontal cortex activity; further research is needed to explore this.

Cingulate Cortex Activations

There was one major similarity in the findings of the studies on Buddhist prayer. Buddhist visualization prayer activated the cingulate cortex (Newberg et al., 2001). Verbal mantra prayer performed by Buddhists was correlated with increased delta activity in the posterior cingulate cortex (Gao et al., 2017). Salat prayer, another example of verbal repetition, also activated the cingulate cortex, but the anterior region (Newberg et al., 2015). Cingulate cortices activation is correlated with higher-effort tasks (Engström et al., 2015), such as the attention-focusing required for these forms of prayer.

Parietal Lobe Activations

The parietal lobe is involved in sensory perception; decreased activity may reflect altered spatial awareness or a sense of oneness (Newberg et al., 2015). The parietal lobe was activated in both forms of conversational prayer (Neubauer et al., 2013; Schdoejt et al., 2009) but decreased during Buddhist visualization meditation (Newberg et al., 2001), Catholic verbal mantra prayer

(Newberg et al., 2003), and both forms of Muslim prayer (Newberg et al., 2015). Conversational prayer creates a dialogue with God rather than focusing on worship practices. Meditative prayer practices create a different spiritual condition, a sense of oneness, than conversational prayer, which creates a sense of interpersonal connectedness. A more comprehensive study exploring the relationship between neural correlates based on prayer goals versus mechanisms is needed.

Discussion

The broadness of prayer and the diversity of various faiths make a standardized study of its neurological impact difficult. The activated brain regions differed within religious demographics and for each type of prayer. Regions related to the Theory of Mind network were activated during conversational prayer, which was examined exclusively in Christians. A pattern was found for the prefrontal cortex, involved in social behavior as well as cognitive control; the only prayers that did not engage this region were the Islamic practices of Dikhr and salat. The cingulate cortex was engaged during prayer that involved verbal repetition, such as salat and Buddhist mantra prayer as well as Buddhist visualization prayer. Parietal lobe activity consistently decreased, which may reflect altered spatial awareness, except during conversational prayer performed by Christians.

Further studies comparing the impact of denomination versus prayer type would be needed to determine how each variable influences brain activations. The mechanisms (the parts of the body engaged, the degree of focused attention) and the goals of prayer (surrender vs. connectedness, oneness vs. companionship) may influence which brain regions are activated, but further research is needed to clarify. This review could be expanded on by comparing one particular type of prayer across faiths or prayer within a specific religious denomination.

The diversity of brain region activations suggests that there is not one particular region

of the brain associated with prayer, but that complex central nervous system interactions mediate this process in a way that we do not yet fully understand. There is no universal prayer experience, nor is there a universal neural correlate for this practice. No universal neural correlate can be identified based on prayer type or denomination for this review, which suggests that faith is both intersecting and highly varied.

The present study is limited by the lack of representation in empirical literature; most results generated pertained to Christianity. No results were found on the databases exploring Hindu tradition, Jewish tradition, or many other faiths. As neurotheology is still relatively under researched, there is not a diverse representation of prayer practices in databases. This may also be the product of majority bias in scientific research. The neurological impact of other acts of worship, such as hymns or passage recitations, could also be beneficial topics for future research.

Implications

Neurotheology is a field that continues to evolve, and one that requires more diverse representation for holistic analysis. Extending our understanding of faith from the sociological to the scientific by examining neural correlates underpinning prayer gives valuable perspective on a practice of vast spiritual and personal value. Examining faith through the lens of neuroscience allows us to see similarities and differences among all belief systems. This inquiry can unify humans by developing an understanding of and respect for diverse prayer practices, within science and beyond.

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