EEG Spectral Analysis on the Cognitive Neuropsychology of Religious Experiences in Worship with Music

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Abstract

A total of 60 evangelical worshippers were recruited to participate in lab experiments measuring the neurophysiological activity of their religious experiences during worship practices. There were several experimental conditions: resting state, a religious worship song of their own choosing, a religious worship song we provided, a secular song of their choosing, a secular song we provided, a condition without music and a twelve-tone song selected to be disturbing. Apart from the resting state, participants were asked to worship to all conditions while at the same time continuously rating with a bar slider how strongly they sensed the presence of God. We formulated three hypotheses, which upon our analyses were all confirmed: (i) Religious songs show greater neurophysiological activation patterns than secular ones; (ii) the activation effect becomes especially visible when the religious song can be selected by the participants themselves; (iii) the higher the subjectively rated religious experience, the stronger the attentional mechanisms and emotional reactions, which are characterized by a more dominant presence of theta and alpha waves, similar to meditation practice.

Keywords: EEG, spectral analysis, religious experience, phenomenology, worship

Introduction

Religious experiences can be powerful occurrences to the believers who instantiate them. In the literature, there are various philosophically motivated axioms governing the research emerging in this field. One idea is that they are *cognitive byproducts* from our evolutionary history, carrying a beneficial element for the survival of the human species (Kress, 1993). Pascal Boyer (1994) has proposed that religious ideas are deemed as such due to the fact that they belong to a class he refers to as *minimally counterintuitive concepts*. Maximally and minimally intuitive concepts can both be remembered easily but the former strike people as more realistic and hence are incorporated into people's beliefs and perceptions. One famous idea is the *Hyper Active Agency Detection Device*, which states that it is evolutionarily beneficial to see agency where perhaps there is none so that potentially dangerous signals will not be overlooked (Green, 2015). Another view conceptualizes religious inclinations as *pro-social adaptations*. It assumes that the belief in retribution by a divine agent is useful for the stability of a social community since rational choice theory predicts that free riders will try to establish themselves by any means possible (Batara et al., 2016).

Michael Persinger (1983) believed that stimulating the temporal lobes leads to sensing the presence of spiritual beings. In 2002, he did exactly this by means of transcranial magnetic stimulation TMS and claiming that he was successful in inducing such a religious experience (Persinger & Healey, 2002). A later Swedish team, however, was not able to replicate the findings (Granqvist et al., 2005). Drawing from neurological research on religious states of mind, two hypotheses have become famous: (i) the Temporal Involvement Hypothesis (Beauregard, 2011; Beauregard & Paquette, 2008; Granqvist et al., 2005; Persinger, 1983; Persinger & Healey, 2002; Tinoca & Ortiz, 2014), of which Persinger was a vital advocate, and (ii) the Executive Inhibition Hypothesis (Andersen et al., 2014; Deeley et al., 2014; Kapogiannis et al., 2009; Lindeman et al., 2013; Schjoedt, 2009; Schjoedt et al., 2013). The

former claims that religious experiences are triggered by a specific activation of the temporal lobes and the latter holds that an inhibition of frontal executive regions is key.

In order to create a suitable experimental design, researchers have typically put the focus on religious practices, which however, is only one dimension in the subjective construct known as religiosity (Huber & Huber, 2012). Among them, some exotic practices like the ritual of "praying in tongues", also know as glossolalia, have been studied – both at a functional (Newberg et al., 2006) as well as at a structural level (Walter et al., 2020).

Although the neuroscientific literature on religiosity is still scarce, a longitudinal study over the span of two decades found that people who rank their importance of religion and spirituality (often abbreviated with R/S) have higher posterior alpha when measured with EEG, which generally captures the electric potential on the scalp. The dominant alpha did not change substantially when the ratings decline nor did the low levels of alpha increase when after twenty years the self-rated importance of R/S rose. The only change occurred when believers switched their attending denomination, which was accompanied by a decrease of the posterior alpha (Tenke et al., 2017).

A meta-analysis on 25 reports studying the neural correlates of R/S has suggested that the specific brain states of R/S are distinct from their non-R/S counterparts. The regions most often associated with experiential features of R/S are the caudate nucleus, the default mode network, the posterior cingulate network, precuneus, orbitofrontal cortex, and the medial frontal cortex. The authors make the case that "Further studies with more rigorous study designs are warranted to elucidate the neurobiological mechanisms of R/S" (Rim et al., 2019, p. 303).

Research on religious chanting, involving electrophysiological and neuroimaging methods, shows a decrease of the eigenvector centrality in the posterior cingulate cortex, which may

have to do with endogenous delta oscillations. The authors claim that this is not influenced by the heart rate or the respiratory rate. It is not associated with language processing and the neural physiology appears to differ from prayer or mediation (Gao et al., 2019). A follow-up study found that religious chanting recruited several networks that included subcortical regions of the midbrain, amygdala (the left amygdala was more activated than the right one) and the thalamus. At the same time, cortical structures were involved like the fusiform gyrus, the left parietal lobule, and the prefrontal cortex. The authors claim that their experiments state that the prayerful singing of religious songs helps with emotion regulation, especially the coping of stress and negative emotion (Gao et al., 2020).

Religious chanting is often connected with a ritual known as worship where believers, not rarely through the help of music, seek the connection to God. In this respect, a qualitative cognitive model has recently emerged, which has been proposed for a context congruent to our present study. It is known as the *Feedback Loop Model for Religious Worship Experiences*. It states that environmental stimuli, including music prone to facilitate worship, leads to mental stimulation where people can focus on God, which in turn helps to induce a religious experience where people believe to be in a divine encounter and hence sense the presence of God. This model has been significant for the current analyses and it lets us deduce that both religious and self-selected worship songs may cognitively activate a believer stronger than is the case with pre-selected worship songs (Walter, 2021).

It has been argued that Christian prayer, which may share cognitive elements with Christian worship, can be compared with focused attention meditation in the sense that both would recruit attentional and emotional mechanisms, which is physiologically characterized by synchronous activity of theta and alpha waves (Dobrakowski et al., 2020).

Based on these ideas, we formulate three hypotheses for the current study:

Hypothesis 1	Religious songs show greater neurophysiological activation patterns than secular ones.
Hypothesis 2	The activation effect becomes especially visible when the religious song can be selected by the participants themselves.
Hypothesis 3	The higher the subjectively rated religious experience, the stronger the attentional mechanisms and emotional reactions, which are characterized by a more dominant presence of theta and alpha waves, similar to meditation practice.

Materials and Methods

Participants

We have recruited 60 Swiss participants from evangelical churches to perform an experiment in the lab where they were asked to worship silently to different conditions, which the know usually induces an experience where they sense the presence of God. Hence, only believers who can self-reportedly induce this state of mind during worship were recruited and the controls were established with conceptually suitable conditions. Due to a system malfunction, one participant had to be excluded and because of some systematic artifacts, two further participants were discounted. The mean age is 27 years (min: 19y, max: 40y; SD: 4.2y), 87% are right-handed, and the gender ratio is roughly equal (male: 45; female: 55%). The participants are by and large musically talented since 70% of the respondents claim that they play an instrument at least once per week. The highest education is spread out homogenously: 22% hold a master's degree, 23% a bachelor's, 22% a high school diploma and 33% an apprenticeship.

When asked how they experience God during worship, 23% hold that they experience something emotional (whereas 22% say to sense God's presence and 21% feel close to him), 12% believe to sense something physical, and 9% profess to receive a message from God. 11% claim that they get happy during the experience and three respondents (1.5%) report to get melancholic or sad during the experience.

Data acquisition and pre-processing

A structured questionnaire has been filled out by all the participants in order to get an adequate understanding of their experiential dimensions and before the experiments started, informed consent as provided. Each subject performed a hearing test before getting installed in the lab. The experiment began and closed with a 4.5mins resting state session where the participants were asked to close their eyes, be calm and focus only on their breath. There were six conditions where they had the task to try and sink into deep worship and connect with God. They knew that we wanted to measure the physiological responses of them sensing a divine presence. The six conditions were randomized:

- Religious subjective (Rs): respondents brought a worship song that has a proven track record of inducing a religious experience where they usually feel the presence of God. Hence, this song was different for each participant.
- Religious given (Rg): this was a song that was pre-selected by the researchers after conducting qualitative research in order to discover which song might be suitable to be presented as an ideal induction device for this particular cohort. This song was the same for all participants.
- Secular subjective (Ss): respondents brought a secular song that had no religious connotation but was equally liked and associated with positive emotions to the subjects as the Rs song. It had to be similar in style as Rs. Naturally, this song differed for each participant.

- Secular given (Sg): this song had to be comparable to the Rg condition and was selected to be equally favorable. This one was the same for all participants.
- 12-Tone song (S12): we selected an opera tune, which was the same for all subjects. It was a partially dissonant 12-tone sone, deliberately selected for its musical disharmonies in order to create a psychological tension where it becomes harder to focus on God and to engage in the worship experience.
- Empty: here, the participants had to worship God for a 4.5 mins period without music.

Each condition lasted for about 4.5mins and they were separated from one another by a concentration task where they had to memorize letters and correctly estimate whether the last letter in the list was the same as the second-aforegoing one. This concentration task was introduced to prevent any psychological spill-over effect from one condition to the other. Hence, we effectively had an independent observation fore each condition. All participants had to close their eyes for the worship conditions so that we did not measure any visual inputs and associations. On the right-hand side, they had a bar slider where they were able to continuously rate how strongly they sensed the presence of God at any given moment. After each of the conditions they could indicate how well they were able to focus on God on a Likert Scale with four options.

The electrophysiological potential on the scalp was measured using the Brain Products actiCap^{TM} system with 64 active electrodes. The electrode FCz was used as the reference point. The sampling rate occurred with 500 Hz and the sampling interval 2,000 µS.

The raw data was pre-processed with Brain Vision Analyzer 2.2^{TM}. Preprocessing was performed in two steps (cf. C. Mikutta et al., 2012; C. A. Mikutta et al., 2014): (i) the creation of clean data, meaning that it was corrected for artifacts created by eye movement and muscular activity, and (ii) the creation of segmented data, which produced separate files for the different experimental conditions that was ready to use for our analyses.

The first step started with working on a separate session (called the “rest session”), which was recorded before the experiment started. This session was used for each subject to create a filter to correct for the person’s eye movement. In both the rest session and the experimental raw data, channels with systematic artefacts were topographically interpolated. For eye movement correction, an IIR filter was applied at 1.5 to 20 Hz in the rest session. An independent component analysis (ICA) yielded the factors that contributed most to explaining the variance of the data. The relevant factors responsible were excluded for the creation of a subject-dependent filter. This filter, which was created in the rest session, was then applied to each individual subject’s experimental raw data by using a linear derivation model. Raw data inspection was performed visually for each of the participants to exclude local movement artifacts. Before the revised EEG data was exported, it was transformed by weighing against the average reference FCz.

In the second step, the EEG chart was split up so that a separate segment for each experimental condition emerged. The resting state at the beginning and at the end were fused in order to get one resting state segment. After this, a temporal segmentation was performed to get a division of equal sized segments (2 sec), followed by a Fast-Fourier Transformation (FFT) on all the parts. The results were averaged for all the temporal segments so that there was a single file for each experimental condition. A first contrast inspection was performed to get a first feeling for the data before the files were exported as ASC-files.

Data analysis

The ASC-files were imported into Ragu, a matlab toolbox specifically created to work on EEG spectral analysis (Koenig et al., 2011). Several tests were applied to the data (Habermann et al., 2018):

- One-factorial analysis of the different experimental conditions (with TANOVA, followed up by T-maps)
- Two-factorial analysis of the different classes of experimental conditions (with TANOVA, followed up by T-maps)
- Correlations of the average rating (subjective experience of God's presence) from each condition with the EEG data

The EEGs were analyzed by using 8 frequency bands:

Band 1	Upper Delta (1.5 – 3.5 Hz)
Band 2	Lower Theta (3.5 – 6 Hz)
Band 3	Upper Theta (6 – 8.5 Hz)
Band 4	Lower Alpha (8.5 – 10.5 Hz)
Band 5	Upper Alpha (10.5 – 12.5 Hz)
Band 6	Lower Beta (12.5 – 18.5 Hz)
Band 7	Middle Beta (18.5 – 21 Hz)
Band 8	Upper Beta (21 – 30 Hz)

Results

A one-factorial analysis shows that the resting state condition appears to be visually distinct in the multi-dimensional scaling (MDS) in all frequency bands. For this reason, the resting state is excluded for further analyses, which demonstrates a strong topographical difference in the MDS between the empty condition, the S12 and the Rs condition for upper delta waves and a similarly strong difference in the upper alpha band for S12, empty and Ss. This shows that all the relevant conditions are sufficiently distinct from the subjects at rest and that the empty as well as the S12 conditions have been adequately selected as useful controls. Furthermore, it indicates that there is something interesting going on with the Rs and the Ss conditions.

These findings are followed up with a two-factorial design where one factor comprises of the religious (Rs + Rg) and the secular (Ss + Sg) dimensions and the other consists of the self-selected (Rs + Ss) and the pre-selected (hereafter denoted as "given"; Rg + Sg)) dimensions. The Topographical Analysis of Variance TANOVA based on these contrasts yields significant effects for the religious/secular factor in the upper beta frequencies ($p<0.05$) and significant effects for the self-selected/given factor in the in the beta bands ($p<0.05$). There is a significant interaction between the two factors in the lower beta band. As seen in figure 1, the Rs condition appears to be most distinct from the Ss condition.

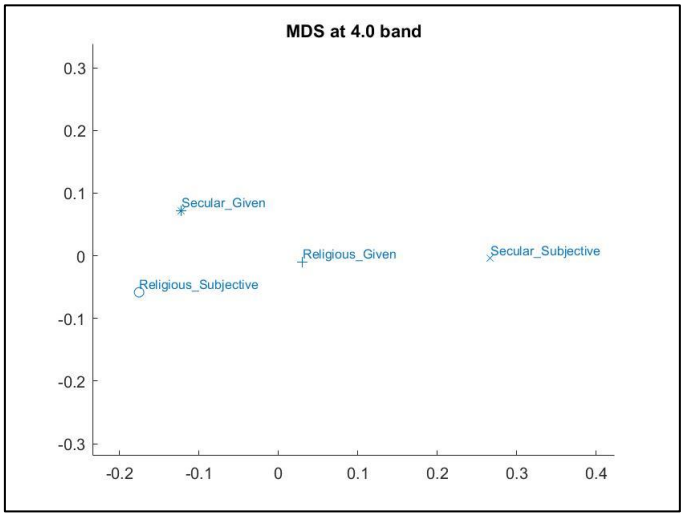

Figure 1. Multi-dimensional scaling (MDS) of the interaction with the four conditions in the two factors at band 4.

These findings are followed up with T-maps at the fourth band to distinguish the different effects, which illustrate a topographic distribution of the associated T-values. As suspected from the MDS, a significant effect is found between Rs and Ss (TANOVA: 0.030; t-min: -3.674 at CP2; t-max: -0.903 at T7; cf. Figure 2).

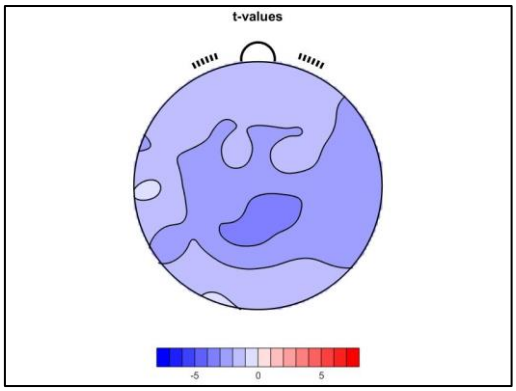

Figure 2. T-map of difference between Rs (positive contrast) and Ss (negative contrast) at frequency band 4.

As seen in Figure 2, there are less alpha waves in Rs than in Ss, which means that among the self-selected songs, the religious worship condition is associated with a higher mental activity.

This is further tested through a T-value analysis where the religious conditions (Rs + Rg) are compared with the secular ones (Ss + Sg). Since the original TANOVA yielded a significant effect in band 8, it is not surprising that we find a significant difference in the respective T-maps, as seen in Figure 3 (TANOVA: 0.009; t-min: -0.579 at PO3; t-max: 3.405 at TP7).

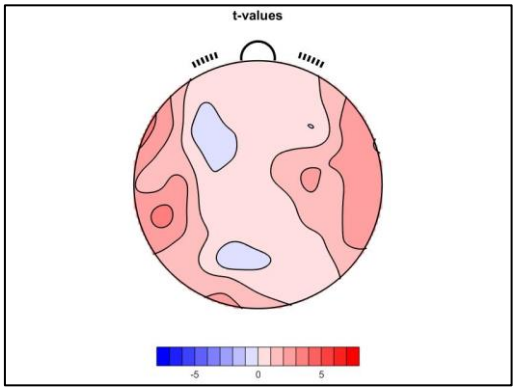

Figure 3. T-map of difference between the religious conditions (positive contrast) and the secular ones (negative contrast) at frequency band 8.

Figure 3 illustrates that by and large there are more upper beta waves present in the religious conditions as compared to the secular ones. This is consistent with the statement from before that there is a stronger activity in the religious subjective condition.

Although there are significant differences when the self-selected songs (Rs + Ss) are compared with the given situations (Rg + Sg) at the sixth band (TANOVA: 0.053; t-min: -1.510 at C2; t-max: 2.546 at PO8), the seventh band (TANOVA: 0.016; t-min: -1.533 at FC3; t-max: 3.756 at TP9) and at the eighth band (TANOVA: 0.006; t-min: -3.030 at C1; t-max: 3.906 at TP9), this discrimination does not tell us anything about the religious component.

A major point of interest lies in the connection between the subjective religious experience itself, measured as a continuous rating of the worshipper's intensity of sensing God's presence, and the topographic EEG wave dispersions for each experimental condition. In order to exclude the individual background noise, the average ratings from the empty condition was subtracted from the other conditions for each person. These differences are correlated via a one-factorial within-subject-design with the topographical difference maps, where the empty condition is located on the first contrast and the condition of interest is located on the second contrast. For the difference between Rs and empty, there are significant interactions with the average rating of the religious experience at band 3 and band 4 ($p<0.05$). Similarly, there is a significant interaction between the difference of Ss and empty with the average rating at band 1 and band 2 ($p<0.05$).

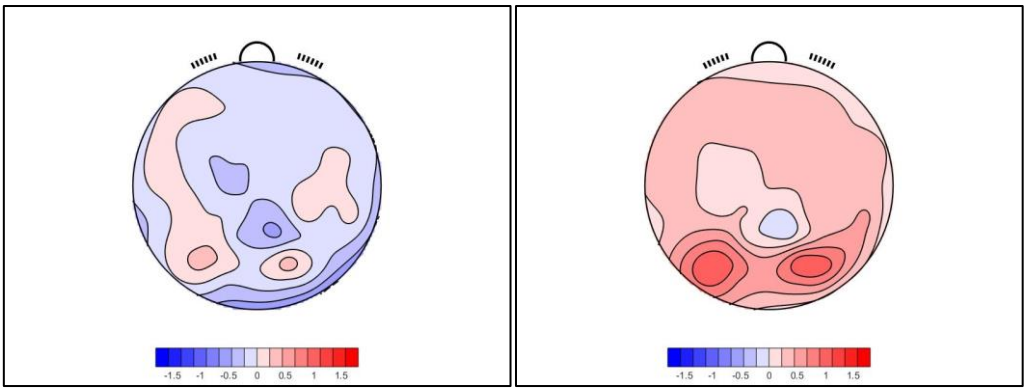

Figure 4a (left). T-map of empty condition from band 3 to band 4.

Figure 4b (right). T-map of Rs condition from band 3 to band 4.

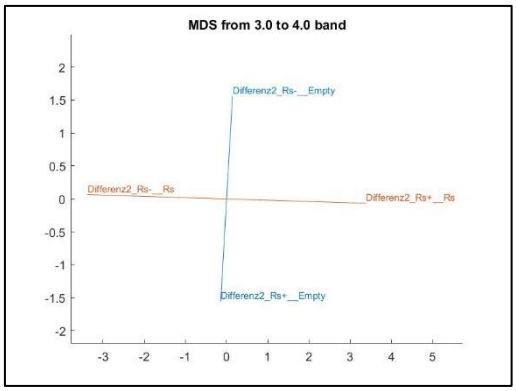

Figure 4c. Interaction between Rs and empty for the average experiential ratings and the topographic difference maps in an MDS for the average of the bands 3 to 4.

As seen in Figures 4a-c, in the Rs condition, there is more upper theta and lower alpha the stronger the religious experience becomes. This result manifests most strongly in the occipital region.

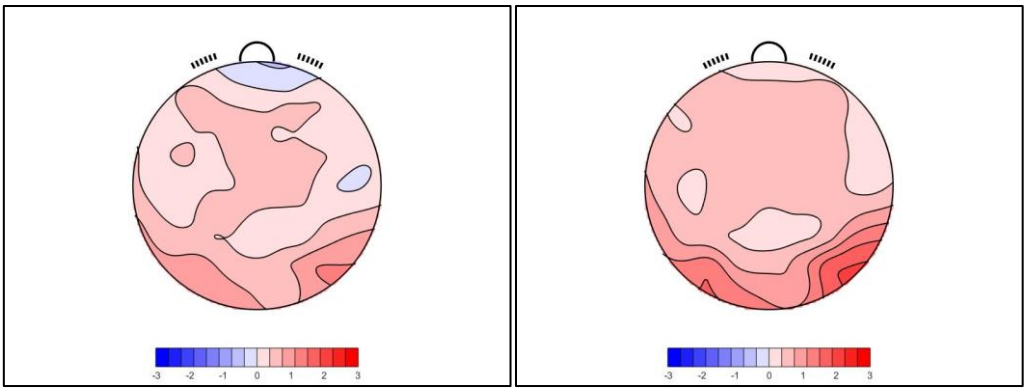

Figure 5a (left). T-map of empty condition from band 1 to band 2.

Figure 5b (right). T-map of Ss condition from band 1 to band 2

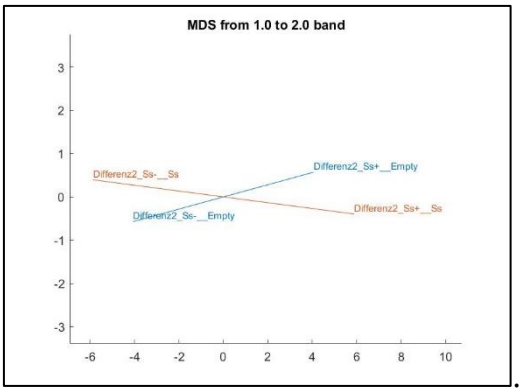

Figure 5c. Interaction between Ss and empty for the average experiential ratings and the topographic difference maps in an MDS for the average of the bands 1 to 2.

Figures 5a-c show that there are more upper delta and lower theta waves in the Ss condition when the religious experience gets more intense.

Discussion

Our study makes no significant contribution to the ideas in the literature concerning the Temporal involvement Hypothesis (Beauregard, 2011; Beauregard & Paquette, 2008; Granqvist et al., 2005; Persinger, 1983; Persinger & Healey, 2002; Tinoca & Ortiz, 2014) or the Executive Inhibition Hypothesis (Andersen et al., 2014; Deeley et al., 2014; Kapogiannis et al., 2009; Lindeman et al., 2013; Schjoedt, 2009; Schjoedt et al., 2013) of religious

experiences. Although there are more upper beta waves in the temporal regions when the religious songs are compared to the secular ones, the comparison of Rs with Ss showed no such thing and the results pertaining to the experiential dimension are localized most strongly in the occipital region. If anything, one would have to reformulate the idea towards an Occipital Involvement Hypothesis with the association of lower EEG frequencies (bands 1 to 4, depending on the experimental condition).

At first sight, it looks as though some of the findings are contradictory. On the one hand, there are less lower alpha waves when the religious setting is observed but on the other hand, there are more lower alpha frequencies when the religious experience is analyzed in exactly the same setting. It is, however, only superficially in conflict with each other because upon closer inspection, it is relevant to appreciate what statistical operations are performed in the different analyses. In other words, it is not the case that the same operations yield differing results but that in one calculation, we perform a regression and see that there is more alpha in the perception of God's presence during the religious condition and in the other calculation, religious conditions are compared to secular ones, which in turn results in a reduction of alpha for the religious setting.

Conceptually, the results can be best understood when we distinguish between two phenomenological qualities that are both present in the data at hand. The first quality is the "religious experience", which here is operationalized as the measurement of how strongly the participants sense God's presence during the worship practice within any experimental condition. The second quality is the "religious element" that is either present or absent in the settings of the different conditions. These two qualities are worth discussing in light of the obtained results of the present study.

Let us first turn to the experiential quality. The subjective experience of God's presence during the worship practice of each individual was correlated with the EEG frequency bands

for each experimental condition. As already stated, the cognitive model for religious worship experiences used for our third hypothesis (Walter, 2021) lends reason to assume that the religious experience will be qualitatively deeper when the songs can be selected by the participants themselves and when then, additionally, the song is a known worship song which the participant is used to. This is congruent with our discovery that both Ss and Rs show a positive correlation with the averaged experiential ratings. There are thus two important results shedding light on the experiential quality.

First, there is a significant interaction when the subjective ratings of the experience are correlated with the third and fourth frequency bands in the Ss condition. In other words, we find more upper delta and lower theta waves when participants were worshipping to a secular song of their own choosing and having a stronger religious experience. The stronger the experience becomes, the more of these waves are present when people worship to a non-religious song they already know. Hence, even without the "religious element" immanent in the environmental context, people showed a clear neurocognitive reaction to the religious experience. Functionally, these bands are often associated with rest, deep states, emotionality, creativity and insight (Stern & Engel, 2013). This means that with self-selected secular songs, participants are in a relaxed state where they are able to sink into the experience of feeling the presence of God. The stronger the experience gets, the more we find this "deep state" where it becomes emotionally stronger, which may also be accompanied by some creative insight.

The second finding pertaining to the experiential quality is the positive association of the ratings relating to the perception of God's presence with the upper theta and lower alpha bands in the Rs condition. It implies that the stronger the religious experience becomes, when people worship to religious songs they already know, the more theta and alpha waves are present. This is typically associated with heightened emotion and awareness (Stern & Engel, 2013). When these activation patterns are observed, there appears to be an intriguing

resemblance to meditation, which is likewise accompanied with theta and alpha frequencies that are associated with calm awareness and focus (Deolindo et al., 2020).

Both of these findings concerning the experiential quality are consonant with the previous understanding that environmental factors, such as the musical setting, can foster a worshipper's focus on God and lead to more vivid religious experiences. It appears like the perception of God's presence in the Ss condition comes along with a more slumbering and calm state that is accompanied with some emotionality in a deep state of rest (cf. Stern & Engel, 2013). Our data agrees with the previous cognitive models that the Rs condition comes along with a stronger focus on God and also with a more vivid and active state of mind (Walter, 2021), although it should not be concluded that they exit the calm state. There, a stronger experience comes along with more theta and alpha waves, implying that – perhaps being in an almost meditative state (Deolindo et al., 2020; Dobrakowski et al., 2020) – the respondents become more active, with a heightened emotionality and awareness.

Next, let us turn to the quality of the "religious element". As seen before, a stronger religious focus in the environmental factors leads to stronger mental activity signaled by higher EEG frequencies. This is corroborated when the conditions with the religious element are compared to the secular conditions. The religious songs (Rs + Rg) are compared with the secular songs (Ss + Sg), which yielded an increase in the upper beta waves for the religious conditions. This implies that when the religious elements are present (a song that has a religious connotation based on the text and the recognition effect), more cognitive activity is present, which neurophysiologically manifests itself with stronger perception, thinking, focus and sustained attention (cf. Stern & Engel, 2013).

These processes are even further strengthened by the fact that there is a decrease in lower alpha frequencies when Rs is compared to Ss. Here, there is a specific focus on the religious element because in both conditions the participants worshipped to self-selected songs and the

only difference is that one is a religious worship song they know and the other one is a secular song they know. The decrease of alpha in this comparison can generally be regarded as the preponderance of more active thinking (cf. Kardan et al., 2020; Kraus et al., 2019).

Although it looks like the decreased alpha in Rs disagrees with the increased alpha during the heightened religious experience during Rs, it is not an actual contradiction. The first deals purely with the religious element, which comes along with more focus and active thinking, and the religious experience is associated with more awareness and emotionality. It is no contradiction in terms to conclude that the sensation of God's presence invokes a calm state of mind with heightened emotion and awareness and that at the same time it comes along with a stronger focus and perception of God.

Much to the contrary, this is in agreement with the previously discussed qualitative cognitive model for religious worship experience, which predicts that a stronger focus on God can lead to a heightened awareness and perception thereof (Walter, 2021). We can now add to this the discovery that it is also emotional experience and that the subjective descriptions match the neurocognitive underpinnings. There are striking parallels to the activation patterns in meditation, although it may perhaps be a more cognitively active state because of the religious element that comes along with the activation of upper beta waves.

Conclusion, limitations, and future research

There is a uniform picture emerging from this study: when people start to worship and feel comfortable enough to open up (indicated by the ratings during the Ss condition), the believers get into a calm and deep state with latent emotionality and creativity. In this state, some people may perhaps have the impression to receive some new spiritual insights since problem solving, feelings and insight is sometimes associated with the preponderance of delta and theta oscillations (Stern & Engel, 2013). Once people get into a strong religious

experience in an environment where they feel most comfortable (as indicated by the ratings of the Rs condition), their mind becomes more active with strong awareness and emotion. This cognitive activation in the experience is dependent upon the presence of the religious element (which comes along with lower alpha and increased upper beta waves) – and this is exactly the key difference to the meditation practices. Meditation is often characterized by theta and alpha, and it is functionally associated with calm attention and awareness (Deolindo et al., 2020). Whereas this is also the case for religious experience, measured here as the intensity of the sensation of God's presence, it is associated with more emotion, perception and active thinking.

There may be a simple reason for this – and perhaps it is worth posing as a hypothesis for future studies: worship and the associated religious experiences are a process where the believer actively focusses on God (Walter, 2021). Hence, the cognitive processes might be centered around this central mental construct. The person's attention is directed outward to sense the connection with the divine. There is an active search for the divine, which is a mental activity featured by attentiveness, awareness, and focus. Likewise, once the experience gets stronger, the perception of the divine gets more intense and this in turn is characterized by stronger emotional reactions. This means that an experience of the divine during worship may be a meditative state with the added cognitive dimensions of higher emotion and active thinking. The dynamics are illustrated in Figure 6.

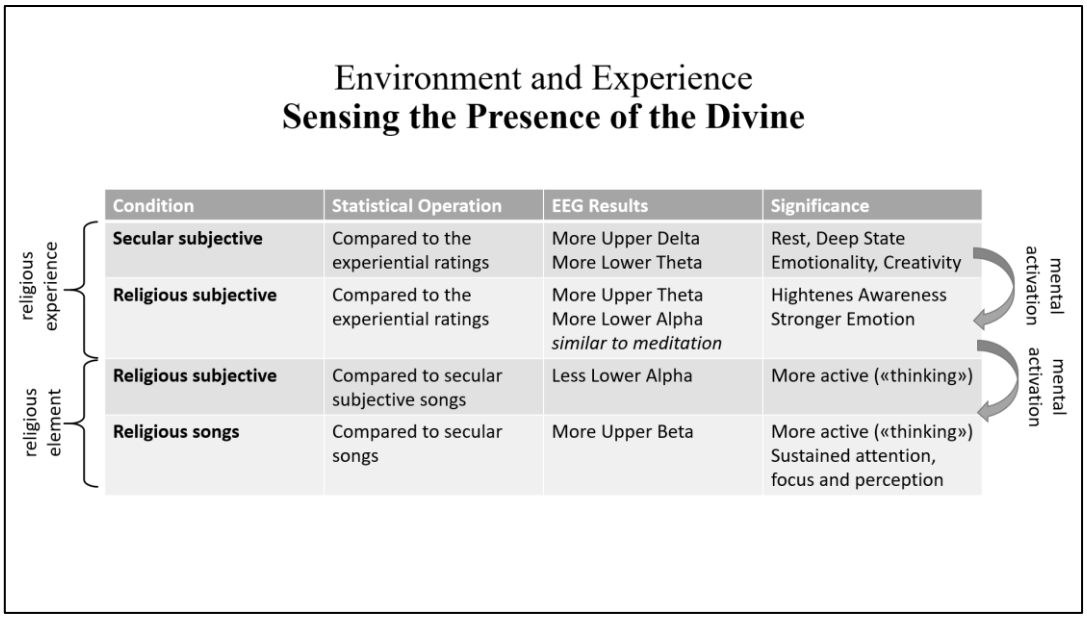

Figure 6. Summary of the obtained results, which illustrates the increased mental activity in the experience through the religious element.

These ideas are well situated with our current cognitive models in both meditation (Deolindo et al., 2020) as well as religious worship experiences with music (Walter, 2021). As such, they are well worth being posed as hypotheses in future investigations. Likewise, the above mentioned Occipital Involvement Hypothesis might be an interesting hypothesis for the future as well, since our data shows that the increased experience of the divine comes along with more delta, theta and lower alpha waves in the occipital regions.

In short, we are able to accept our first hypothesis, which assumes that religious songs show greater neurophysiological activation patterns. This is mostly due to the presence of upper beta waves. When the participants select the songs themselves, there is less lower alpha in the religious condition, which would corroborate the finding, as the second hypothesis would predict. Hypothesis 2 can therefore also be accepted. The third hypothesis can equally be accepted since the attentional mechanisms and emotional reactions increase from the secular self-selected song to the religious one.

The major limitation in the resent study is due to the complex nature of these kinds of phenomenal states in the religious domain. First, we have studied one specific phenomenon that belongs to a wider class of "religious experiences". There are many more experiences that can be deemed religious that may not necessarily be characterized as "sensing the presence of God" (Taves, 2005, 2011; Taves et al., 2019). Second, there are likely different psychological mechanisms that may lead to the various instances of such states of mind (as already highlighted by James, 1902). And third, in order to have a strong validity in our operationalization, we have selected a narrow population of evangelical Christians who share their theological presuppositions concerning such experiences. Other denominations and religions have different dogmatic concepts and hence cognitive constructs associated with such experiences. It is therefore possible that the neurophysiological mechanisms may also differ in these respects. These things are worth further studying in the future.

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We have been able to recruit 60 participants for a study that touches on very intimate subject to all of them. They deserve our fullest appreciation since it cannot be taken for granted that so many people are willing to worship and offer their most intimate experiences under sterile lab condition.

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References

Andersen, M., Schjoedt, U., Nielbo, K., & Sørensen, J. (2014). Mystical Experience in the Lab. *Method & Theory in the Study of Religion, 26*, 217–245. https://doi.org/10.1163/15700682-12341323

Batara, J. B. L., Franco, P. S., Quiachon, M. A. M., & Sembrero, D. R. M. (2016). Effects of religious priming concepts on prosocial behavior towards ingroup and outgroup. *Europe's Journal of Psychology*, *12*(4), 635–644. https://doi.org/10.5964/ejop.v12i4.1170

Beauregard, M. (2011). Neuroscience and Spirituality – Findings and Consequences. In H. Walach, S. Schmidt, & W. B. Jonas (Eds.), *Neuroscience, Consciousness and Spirituality* (Vol. 1, pp. 57–73). Springer Netherlands. https://doi.org/10.1007/978-94-007-2079-4_4

Beauregard, M., & Paquette, V. (2008). EEG activity in Carmelite nuns during a mystical experience. *Neuroscience Letters*, *444*(1), 1–4. https://doi.org/10.1016/j.neulet.2008.08.028

Boyer, P. (1994). *The Naturalness of Religious Ideas: A Cognitive Theory of Religion*. University of California Press.

Deeley, Q., Oakley, D. A., Walsh, E., Bell, V., Mehta, M. A., & Halligan, P. W. (2014). Modelling psychiatric and cultural possession phenomena with suggestion and fMRI. *Cortex*, *53*, 107–119. https://doi.org/10.1016/j.cortex.2014.01.004

Deolindo, C. S., Ribeiro, M. W., Aratanha, M. A., Afonso, R. F., Irrmischer, M., & Kozasa, E. H. (2020). A Critical Analysis on Characterizing the Meditation Experience Through the Electroencephalogram. *Frontiers in Systems Neuroscience*, *14*, 1–29. https://doi.org/10.3389/fnsys.2020.00053

Dobrakowski, P., Blaszkiewicz, M., & Skalski, S. (2020). Changes in the Electrical Activity of the Brain in the Alpha and Theta Bands during Prayer and Meditation. *International Journal of Environmental Research and Public Health*, *17*(24), 9567. https://doi.org/10.3390/ijerph17249567

Gao, J., Leung, H. K., Wu, B. W. Y., Skouras, S., & Sik, H. H. (2019). The neurophysiological correlates of religious chanting. *Scientific Reports*, *9*(1), 4262. https://doi.org/10.1038/s41598-019-40200-w

Gao, J., Skouras, S., Leung, H. K., Wu, B. W. Y., Wu, H., Chang, C., & Sik, H. H. (2020). Repetitive Religious Chanting Invokes Positive Emotional Schema to Counterbalance Fear: A Multi-Modal Functional and Structural MRI Study. *Frontiers in Behavioral Neuroscience*, *14*, 1–12. https://doi.org/10.3389/fnbeh.2020.548856

Granqvist, P., Fredrikson, M., Unge, P., Hagenfeldt, A., Valind, S., Larhammar, D., & Larsson, M. (2005). Sensed presence and mystical experiences are predicted by suggestibility, not by the application of transcranial weak complex magnetic fields. *Neuroscience Letters*, *379*(1), 1–6. https://doi.org/10.1016/j.neulet.2004.10.057

Green, A. (2015). The Mindreading Debate and the Cognitive Science of Religion. *Sophia*, *54*(1), 61–75. https://doi.org/10.1007/s11841-014-0450-0

Habermann, M., Weusmann, D., Stein, M., & Koenig, T. (2018). A Student's Guide to Randomization Statistics for Multichannel Event-Related Potentials Using Ragu. *Frontiers in Neuroscience*, *12*, 355. https://doi.org/10.3389/fnins.2018.00355

Huber, S., & Huber, O. W. (2012). The Centrality of Religiosity Scale (CRS). *Religions*, *3*(3), 710–724. https://doi.org/10.3390/rel3030710

James, W. (1902). *The Varieties of Religious Experience* (Centenary Edition). Taylor & Francis.

Kapogiannis, D., Barbey, A. K., Su, M., Zamboni, G., Krueger, F., & Grafman, J. (2009). Cognitive and neural foundations of religious belief. *Proceedings of the National Academy of Sciences*, *106*(12), 4876–4881. https://doi.org/10.1073/pnas.0811717106

Kardan, O., Adam, K. C. S., Mance, I., Churchill, N. W., Vogel, E. K., & Berman, M. G. (2020). Distinguishing cognitive effort and working memory load using scale-

invariance and alpha suppression in EEG. *NeuroImage*, *211*, 116622. https://doi.org/10.1016/j.neuroimage.2020.116622

Koenig, T., Kottlow, M., Stein, M., & Melie-García, L. (2011). Ragu: A Free Tool for the Analysis of EEG and MEG Event-Related Scalp Field Data Using Global Randomization Statistics. *Computational Intelligence and Neuroscience*, *2011*, 1–14. https://doi.org/10.1155/2011/938925

Kraus, B., Cadle, C., & Simon-Dack, S. (2019). EEG alpha activity is moderated by the serial order effect during divergent thinking. *Biological Psychology*, *145*, 84–95. https://doi.org/10.1016/j.biopsycho.2019.04.003

Kress, O. (1993). Oliver Kress - A new approach to cognitive development: Ontogenesis and the process of initiation. *Evolution and Cognition*, *2*, 319–332.

Lindeman, M., Svedholm, A. M., Riekki, T., Raij, T., & Hari, R. (2013). Is it just a brick wall or a sign from the universe? An fMRI study of supernatural believers and skeptics. *Social Cognitive and Affective Neuroscience*, *8*(8), 943–949. https://doi.org/10.1093/scan/nss096

Mikutta, C. A., Maissen, G., Altorfer, A., Strik, W., & Koenig, T. (2014). Professional musicians listen differently to music. *Neuroscience*, *268*, 102–111. https://doi.org/10.1016/j.neuroscience.2014.03.007

Mikutta, C., Altorfer, A., Strik, W., & Koenig, T. (2012). Emotions, Arousal, and Frontal Alpha Rhythm Asymmetry During Beethoven's 5th Symphony. *Brain Topography*, *25*(4), 423–430. https://doi.org/10.1007/s10548-012-0227-0

Newberg, A. B., Wintering, N. A., Morgan, D., & Waldman, M. R. (2006). The measurement of regional cerebral blood flow during glossolalia: A preliminary SPECT study. *Psychiatry Research: Neuroimaging*, *148*(1), 67–71. https://doi.org/10.1016/j.pscychresns.2006.07.001

Persinger, M. A. (1983). Religious and Mystical Experiences as Artifacts of Temporal Lobe Function: A General Hypothesis. *Perceptual and Motor Skills*, *57*(3_suppl), 1255–1262. https://doi.org/10.2466/pms.1983.57.3f.1255

Persinger, M. A., & Healey, F. (2002). Experimental facilitation of the sensed presence: Possible intercalation between the hemispheres induced by complex magnetic fields. *The Journal of Nervous and Mental Disease*, *190*(8), 533–541. https://doi.org/10.1097/00005053-200208000-00006

Rim, J. I., Ojeda, J. C., Svob, C., Kayser, J., Drews, E., Kim, Y., Tenke, C. E., Skipper, J., & Weissman, M. M. (2019). Current Understanding of Religion, Spirituality, and Their Neurobiological Correlates. *Harvard Review of Psychiatry*, *27*(5), 303–316. https://doi.org/10.1097/HRP.0000000000000232

Schjoedt, U. (2009). The Religious Brain: A General Introduction to the Experimental Neuroscience of Religion. *Method & Theory in the Study of Religion*, *21*(3), 310–339. https://doi.org/10.1163/157006809X460347

Schjoedt, U., Sørensen, J., Nielbo, K. L., Xygalatas, D., Mitkidis, P., & Bulbulia, J. (2013). Cognitive resource depletion in religious interactions. *Religion, Brain & Behavior*, *3*(1), 39–55. https://doi.org/10.1080/2153599X.2012.736714

Stern, J. M., & Engel, J. (2013). *Atlas of EEG Patterns* (2nd edition). Lippincott Williams & Wilkins.

Taves, A. (2005). Religious experience. In *Encyclopedia of religion* (2nd edition). Thompson-Gale.

Taves, A. (2011). *Religious experience reconsidered: A building-block approach to the study of religion and other special things* (Second printing, and first paperback printing). Princeton University Press.

Taves, A., Wolf, M. G., Ihm, E. D., Barlev, M., Kinsella, M., & Vyas, M. (2019). *What Counts as Religious Experience? The Inventory of Nonordinary Experiences as a Tool*

for Analysis across Cultures [Preprint]. PsyArXiv. https://doi.org/10.31234/osf.io/ux28d

Tenke, C. E., Kayser, J., Svob, C., Miller, L., Alvarenga, J. E., Abraham, K., Warner, V., Wickramaratne, P., Weissman, M. M., & Bruder, G. E. (2017). Association of posterior EEG alpha with prioritization of religion or spirituality: A replication and extension at 20-year follow-up. *Biological Psychology*, *124*, 79–86. https://doi.org/10.1016/j.biopsycho.2017.01.005

Tinoca, C. A., & Ortiz, J. L. (2014). Magnetic Stimulation of the Temporal Cortex: A Partial "God Helmet" Replication Study. *Journal of Consciousness Exploration & Research*, *5*(3), 234–257.

Walter, Y. (2021). Towards a Qualitative Model of Religious Worship Experiences: Perceived encounters with the divine in the ritual context of musical devotion practices. *American Journal of Qualitative Research*, *5*(1), 94–141. https://doi.org/10.29333/ajqr/10814

Walter, Y., Dieguez, S., Mouthon, M., & Spierer, L. (2020). Brain structural evidence for a frontal pole specialization in glossolalia. *IBRO Reports*, *9*, 32–36. https://doi.org/10.1016/j.ibror.2020.06.002