Investigating Placebo-Induced Unusual Experiences: A Multiverse Analysis of Emotional Responses

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Abstract

Psychological research has long been intrigued by unusual states of consciousness (e.g., hallucinations, drug-induced altered states, synesthesia, hypnotic states) due to their potential to reveal the workings of the mind. Researchers employed placebo manipulations within experimental environments to induce and systematically examine various unusual experiences, including mystical experiences, thus contributing to a deeper comprehension of such phenomena. However, the reliance on self-report measures in such studies leaves the results vulnerable to response bias, including the potential influence of social desirability. Therefore, this study employed facial electromyography (fEMG) to assess emotional responses during placebo-induced unusual experiences in a sample of 62 participants. Utilizing a multiverse approach, I analyzed the relationship between objective and reported indicators of the occurrence and intensity of unusual experiences in 54 alternatively processed datasets. While evidence for increased emotional responses during unusual experiences is lacking, post-hoc analyses indicate a positive relationship between emotional responses and self-reported mysticism. However, due to mixed results and small effect sizes, the study does not yield conclusive evidence regarding the authenticity of self-reported unusual or mystical experiences. Further, this study investigated the impact of individual differences on emotional responses during unusual experiences with evidence for a negative association between emotional responses and absorption and a positive association between emotional responses and supernatural beliefs. The outcomes of this study contribute to the endeavor of inducing unusual experiences in a controlled environment by comparing self-reports and objective measures. Additionally, they enhance our comprehension of the impact of personality traits and pre-existing beliefs on placebo-induced unusual experiences.

Layman's Abstract

This study investigated extraordinary experiences such as hallucinations and distorted perceptions of time and the body. By studying these unique phenomena, we hope to gain a better understanding of the inner workings of the mind. In this study, participants were led to believe that a placebo brain stimulation device had the potential to induce unusual and mystical experiences. During a session lasting 45 minutes, participants were instructed to indicate the occurrence and intensity of any unusual experiences. However, participants' reports may be influenced by response biases, such as the tendency to present themselves in a socially desirable manner. Therefore, this study additionally measured emotion using electrodes attached to muscles responsible for smiling and frowning. We then compared what people reported with what we measured to see if they matched up. The data was processed in 54 alternative ways to show how robust the findings are when implementing slightly different processing choices. Evidence for increased emotional responses during unusual experiences is lacking, but we did find a connection between emotional responses and people reporting mystical experiences. However, because the results were mixed and the effects were small, we cannot make any definitive conclusions regarding the authenticity of participants' self-reports. We also looked at how individual differences play a role in emotional responses during unusual experiences. We found that people who have a higher tendency to become absorbed in their experience tended to have less emotional responses. On the other hand, those who held supernatural beliefs had stronger emotional responses. Overall, this study contributes to the challenge to induce authentic unusual, and mystical experiences in an experimental environment and gives insight into how personalities and beliefs can influence our responses to placebos.

Investigating Placebo-Induced Unusual Experiences: A Multiverse Analysis of Emotional Responses

Interest in altered or unusual states of consciousness (e.g., hallucinations, drug-induced altered states, synesthesia, hypnotic states) has been on the rise among the general public and academics. The study of such unusual experiences has informed the development of therapeutic methods (Carhart-Harris & Goodwin, 2017; Ramondo et al., 2021; Yaden & Griffiths, 2020) and theories of brain function (Corlett et al., 2019; Fletcher & Frith, 2008; Oakley & Halligan, 2013). However, the precise psychological, biological, and sociocultural mechanisms responsible for these states remain elusive. Especially the characterization of unusual experiences often described as mystical, spiritual, or religious, poses significant challenges. This challenge is evidenced by the lack of consensus among prevailing views and definitions in this field (James, 1902; Andersen et al., 2014; Cardeña et al., 2014; Taves, 2020; Levin & Steele, 2005). With the goal of conducting systematic experimental investigations into unusual experiences, several studies have induced mystical and comparable experiences in a controlled environment using sensory deprivation (Lloyd et al., 2011), expectancy manipulations (Maij & van Elk, 2018; French et al., 2009), a combination of the two (Andersen et al., 2014; Granqvist et al., 2005; Maij et al., 2019; van Elk, 2015), sleep deprivation (Waters et al., 2018), hallucinogens (Preller & Vollenweider, 2016), and hypnosis (Casale et al., 2012).

The empirical study of unusual experiences, however, bears several limitations, such as the lack of reliable induction methods and the reliance on self-report measures to assess the phenomenological content of the experiences (Andersen, et al., 2014; Taves 2011; Sanders & Zijlmans, 2021). In the upcoming section, I introduce the “God Helmet” as a proven method for eliciting unusual experiences using a placebo manipulation. I then review previous findings and potential underlying mechanisms of the phenomena. Building on this foundation, I identify a gap in existing assessment methods in that they heavily rely on self-report. This leads me to propose a physiological measure of valence, aiming to serve as a novel and objective indicator of the intensity and personal significance of placebo-induced unusual experiences. I then propose hypotheses to test the alignment between subjective and physiological indicators of the occurrence and intensity of unusual experiences. Additionally, I put forth hypotheses on the impact of individual differences on physiological responses during unusual experiences.

The God Helmet Method

The first iteration of the God Helmet comprised solenoids attached to a snowboard helmet, which produced weak, complex electromagnetic fields over the brain’s temporal regions. Allegedly, this stimulation caused unusual experiences such as out-of-body experiences or the sensing of another person's presence in the room (Persinger et al., 2010). The failure of a replication study to find a causal role of electromagnetic stimulation led to criticism of previous God Helmet studies, citing insufficient blinding and randomization (Granqvist et al., 2005; Schjoedt, 2009; Andersen et al., 2014; cf. Persinger & Koren, 2005). Nevertheless, the occurrence of unusual experiences (e.g. visual and auditory hallucinations, sense of time or bodily distortions) reported even in the absence of an active intervention instigated a line of research using a sham version of the original God Helmet along with suggestions about its psychological effects to induce unusual experiences in a laboratory environment (Granqvist & Larsson, 2006; Andersen et al., 2014; van Elk, 2015; Maij & Elk, 2018; Maij et al., 2019). The central outcome measures utilized in God Helmet studies have been the EXIT scale (Persinger et al., 2000) and the Mysticism Scale (M-Scale; Hood, 1975). The M-Scale assesses experiences based on phenomenological criteria initially conceptualized by Stace (1960): a profound sense of unity with all that exists, a compelling sense that the experience feels "real" and of intuitive knowledge (noetic quality), a felt sense of sacredness, deeply felt positive mood, transcendence of time and space, and difficulty in explaining the experience in words.

Within placebo God Helmet studies, researchers manipulate participants' expectations through highly suggestive instructions regarding the types of experiences that could be induced by the device (Maij & van Elk, 2018). To further strengthen expectations, researchers have made use of various cues in the physical environment. These cues include presenting participants with neuroscience-related equipment, providing participants with sham electrophysiological measures, or placing a vomit bowl on the table (Maij & van Elk, 2018; Maij et al., 2019; Andersen et al., 2014; van Elk, 2015). While not actively manipulated, the competence and enthusiasm of the experimenter likely further boost expectations (Howe et al., 2017; Thomas & Cooper, 1987; Kaptchuk et al., 2006).

Additionally, researchers have suggested that the extended deprivation of sensory input plays a central role in eliciting unusual experiences with the God Helmet (Granqvist & Larsson, 2006; Maij & Elk, 2018; Andersen et al., 2014; Maij et al., 2017). Psychological research has long recognized that sensory deprivation actively facilitates various hallucinatory experiences (Zubek, 1969), where even 15 minutes in an anechoic chamber (a room designed to stop sound reflections) has resulted in reports reminiscent of those with the God Helmet: participants reported seeing "faces even though no-one was in fact there", "shapes and forms even though they weren't there", sensing "an evil presence even though they couldn't see it" and most rated their experience to be "something very special or important" at least to a slight extent (Mason & Brady, 2009).

Additionally, personality traits and prior beliefs are associated with an individual's susceptibility to the placebo God Helmet method. The trait most consistently associated with the quantity and intensity of unusual experiences with the God Helmet is a participant's tendency to get fully immersed in external sensory events or in mental imagery, measured using the Tellegen Absorption Scale (Tellegen & Atkinson, 1974; Granqvist et al., 2005; van Elk, 2015; Maij & Elk, 2018). Other measures that have been found to correlate with the occurrence of unusual experiences are the adoption of a "new-age'' lifestyle orientation (measured with The New Age Orientation Scale; Granqvist & Hagekull, 2001), and signs of anomalous temporal lobe activity (psychological experiences typically associated with temporal lobe epilepsy; Granqvist et al. 2005; Andersen et al., 2014). These findings caused some to conclude that suggestibility could account for the experiences with the God Helmet. However, Andersen et al. (2014) did not find a connection between individual suggestibility (as more directly measured with the Responsiveness to Suggestibility Scale; Spanos et al., 1983) and unusual experiences. Further, Granqvist & Larsson (2006) found that a higher degree of religiousness predicted a higher occurrence of unusual experiences with a religious quality. Such findings illustrate the complex impact of pre-existing beliefs and personality traits on the experiences with the God Helmet. This explains the wide range of reported phenomena during God Helmet sessions, ranging from weak bodily sensations to meeting a deceased relative and emotional outbursts. In conclusion, the placebo God Helmet has proven a promising method to induce and study unusual experiences in an experimental environment.

Potential Mechanisms

Before discussing the need for this study, it is important to provide an overview of how the phenomenon of the placebo God Helmet has been understood in light of psychological theories. The ability of the God Helmet method to induce unusual experiences is often attributed to the placebo effect. Placebo and nocebo effects respectively refer to the positive or negative changes following inactive treatments or interventions, which can be attributed to psychological and contextual factors beyond statistical confounders (Petrie & Rief, 2019). Several contextual factors such as the administration method (type of pill, injection, sham device; Kaptchuk et al., 2006; De Craen et al., 1999) or the perceived cost of the procedure (Waber et al., 2008; Tinnermann et al., 2017) have been shown to modulate placebo efficacy. Such contextual factors likely alter explicit expectations or predictions regarding one's involuntary responses to interventions. According to expectancy theory, these explicit expectations mediate the placebo effect (Stewart-Williams & Podd, 2004; Petrie & Rief, 2019; Kirsch, 2018). Similarly, experiences with the placebo God Helmet are likely driven by the nature and strength of expectations held by the participant.

To obtain a more mechanistic understanding of placebo effects and experiences with the God Helmet, researchers have connected them to formal computational models of perception. Underlying such models is the view that our perceptual content is constructed rather than passively acquired. Specifically, this view states that the brain generates internal models of various brain-external elements and processes, which it then uses to predict events. Researchers have applied this view to better understand brain-processes like motor control (forward models; Kawato, 1999), reasoning (Johnson-Laird, 1983), theory of mind (Gordon, 1986) and mental imagery (Tian & Poeppel, 2010). A modern, computational representative of this view, the predictive coding framework, holds that the brain is constantly attempting to optimize its model of the world by comparing it to observed input through a version of Bayesian inference (Clark, 2013; Friston & Kiebel, 2009). While the underlying neurobiological mechanisms remain speculative, this framework has been useful in explaining phenomena comparable to God Helmet experiences, such as positive symptoms of schizophrenia (Fletcher & Frith, 2008) and placebo analgesia (decreased pain perception due to placebo treatment; Büchel et al., 2014). Consequently, it has been proposed that this framework provides a potential functional mechanism for God Helmet experiences (Andersen et al. 2014; van Elk, 2015). Strong response expectations ("high-level priors") are passed from higher to lower levels of information processing, thus shaping how signals are interpreted by lower-level mechanisms. Additionally, due to the minimal sensory input, descending predictions are not met with ascending sensory signals that could create a mismatch and prompt adjustment of the predictions (Andersen et al. 2014; van Elk, 2015).

Emotional Experiences Elicited by the God Helmet

One repeating characteristic identified in participants' reports pertains to positive as well as negative emotional experiences that carry large significance (see Table 1 for examples). According to contemporary appraisal theories of emotion (Moors et al., 2013), emotional responses arise from the evaluation of events based on their personal significance and relevance to one's goals and values. According to this theory, nonspecific arousal and other anomalous mental and physiological events during the God Helmet session are cognitively interpreted and labeled (as originally proposed in the two-factor theory; Schachter & Singer, 1962). This labeling process occurs within the framework of individuals' cognitive factors, including beliefs, thoughts, expectations, prior experiences as well as external cues. Consequently, sensations that would be negligible in a different context, are interpreted in accordance with the suggestions given prior to the God Helmet session. Suggestions in God Helmet experiments usually include descriptions of mystical and religious experiences, often mentioning personally significant events with (generally positive) affect (Maij & van Elk, 2018; Maij et al., 2019; Andersen et al., 2014). Contemporary emotion theories align with the predictive processing model discussed in the last section in that they both explain emotional responses during a God Helmet session as a result of the brain's active construction and interpretation of perceptual content.

Table 1

Examples of Emotional Responses in Placebo God Helmet Studies

Examples	Source
"The voice told me that I was ready to get children (…) Deep down I already knew this and I became very emotional and started crying." "I got a pleasant goosebump feeling." "All of a sudden I saw planets that flew past me. I could see it. Saturn and Mercury. (…) I both felt it and saw it. It felt like an enormous expansion into something infinitely great. (…) I sat in the middle of it all with vast space around me. It was tremendously beautiful." "I felt my hair standing up on the right side of my head. (…) It was actually a very fun experience."	Maij et al, 2019
""I had a strong feeling that some other being was present who was watching me. I also felt very angry." "I completely lost sense of my body size. One moment I felt extremely small, another moment I felt like I was blown up and another moment my eyes felt larger than my head. These changes occurred vary rapidly. At the end, I felt like I was leaving my body and was floating through the room"	Maij & van Elk, 2018
"Images from childhood from walks across a summer heath"	van Elk, 2015

Assuming the induction of authentic religious and mystical experiences, emotions are a common occurrence and play a significant role in shaping these experiences (Vishkin, 2021; James, 1902; Stace, 1960; Bradford, 2013). Neurophysiological evidence lends further support for this notion, with findings indicating that "amygdalar, prefrontal, and anterior temporal networks, particularly on the right side, mediate religious experience" (McNamara, 2014, p. 246). Further, Saver and Rabin (1997) propose a limbic marker hypothesis for religious-mystical experience, according to which the temporolimbic system is involved in assigning meaning to certain altered bodily and mental states, “prompting comprehension of these experiences within a religious framework” (p.498). Since the God Helmet has demonstrated the ability to generate personally meaningful and potentially mystical experiences, often accompanied by emotions (as observed and theorized), emotions during unusual experiences with the God Helmet could serve as an indicator of the intensity of these experiences.

Issues With Existing Assessment Methods

Alternative explanations for reports of unusual experiences with the God Helmet pertain to erroneous assessment and fabrication. Research on experiences with the God Helmet has predominantly relied on self-report, with the most common measure being the Mysticism Scale (M-Scale; Hood, 1975). In addition, alternative approaches have also been employed to explore the phenomenological content of these experiences. These include asking participants to rate their experiences in terms of sensory modalities (visual, auditory, haptic; Andersen et al., 2014) and developing categorization schemes based on open-ended verbal descriptions of the experiences (Maij et al., 2019). Further, experiments have made use of response buttons to capture moments of unusual experiences (Maij & van Elk, 2018; Maij et al., 2019; Andersen et al., 2014). In the only study implementing an outcome measure not relying on self-report, van Elk (2015) assessed participants' implicit representation of their body during experiences with the God Helmet using EEG, observing that personality differences relate to neural markers during unusual experiences.

While self-reports have been useful to understand the phenomenological content of experiences with the God Helmet, caveats of such approaches must be considered (de Oliveira Maraldi, 2018). First, by priming participants with the expectation to experience certain unusual experiences and by assessing the unusual experiences using the mysticism construct (M-Scale), participants are provided with a particular framework and terminology with which to understand and describe their experiences. This could lead to responses being especially affected by demand characteristics, where instead of providing honest answers, participants report what they think matches the experimenter’s requirements out of a desire to appear more socially and morally responsible (Strahan & Gerbasi, 1972). Additionally, according to the goal framing theory, certain cues about norm conformity in other people, such as formal attire and neat laboratories, makes it more likely that participants conform to social norms and rules (Lindenberg & Steg, 2007). Since cues about norm conformity are often part of the expectancy manipulation in God Helmet studies, participants are likely further inclined to conform with the experimenter. Furthermore, individuals who incorporate spirituality as an integral part of their identity and express this during the study may exhibit a tendency towards maintaining consistency in their self-representations. This inclination could result in a positive response bias, where participants align their later responses with their earlier ones (Council, 1993). Further, if participants have a mystical experience, such experiences have been characterized as hard to describe, beyond words or ineffable (Stace, 1960), adding an inherent difficulty to conceptualize and communicate such experiences. Introspective abilities (the capacity to monitor, assess and notice one’s own mental and emotional processes) vary substantially across individuals (Fleming et al., 2010), introducing potentially non-random inaccuracy to self-reports. Lastly, experiences with the God Helmet appear to vary strongly across participants. While some people’s experiences might be captured well using the construct of mystical experiences, others might experience unusual sensations and mental imagery that do not resonate with the dimensions used in the M-Scale. Self-report measures therefore do not suffice to establish the authenticity of participant’s experiences. To exhaustively study the variety and weirdness of the experiences people have with the God Helmet, multiple assessment methods should be utilized.

The Current Study

While the importance of physiological measures, like skin conductance, heart rate variability or respiration have been suggested and/or piloted in previous God Helmet studies, no attempt has yet been made to analyze physiological responses to experiences with the God Helmet. Therefore, the objective of this research is to examine physiological responses during a God Helmet session and to compare them to self-reported occurrences and intensity of unusual experiences. Such an alignment between subjective and objective measures would substantiate the authenticity of self-reports.

Electromyographic activity of two facial muscles, namely the corrugator supercilii (related to frowning) and the zygomaticus major (related to smiling), was selected as a physiological assessment. These muscles have been repeatedly shown to differentiate the valence and intensity of affective reactions (Cacioppo et al., 1986; Golland et al., 2018). Given that emotions result from the evaluation of events based on their relevance to one's goals and values (Moors et al., 2013), this physiological measure of emotion should serve as an objective proxy for the intensity and personal significance of experiences. Specifically, activity of the corrugator supercilii muscle appears to decrease linearly with the pleasantness of affective stimuli, making it a reliable indicator of the emotional significance of a given stimulus (Cacioppo et al., 2019; Larsen et al., 2003). Zygomaticus major muscle activity has been shown to linearly increase with the pleasantness of affective stimuli (within pleasant stimuli; Larsen et al., 2003). However, the primary focus of this study is not to examine the valence direction of emotion, but rather to assess the intensity or strength of emotional response, approximated by the absolute deviation from baseline activity of the specified muscles.

The first question asked in this study is whether participants' emotional responses are stronger during unusual experiences than during randomly chosen time windows (Hypothesis 1). Stronger affective responses during periods of unusual experiences would support subjective reports of extraordinary experiences and the involvement of physiological responses indicative of emotion in experiences with the God Helmet.

Further, this study utilized a grip response device that participants used to indicate the moment and strength of an unusual experience. Compared to previous response buttons, this method provides a continuous measure for the intensity of experiences. This study seeks to establish whether the strength of emotional responses during unusual experiences is associated with the corresponding grip strength used to indicate the intensity of unusual experiences (Hypothesis 2).

The second aim of this study was to investigate the link between physiological indicators of experienced intensity during unusual experiences and previously assessed variables, such as reported levels of absorption, supernatural beliefs, and mystical qualities of the experience. Specifically, I hypothesize that the Tellegen Absorption Scale and the M-Scale, measures previously shown to be associated with the intensity and/or frequency of unusual experiences, may also serve as predictors of physiological indicators of increased emotional intensity measured during such experiences (Hypothesis 3). Hypotheses 2 and 3 aim to reveal the relationship between subjective reports (grip strength, self-rated absorption and mysticism) and objective measures (hedonic response).

Moreover, I predict that participants believing in supernatural concepts would experience stronger emotions during unusual experiences (Hypothesis 4). This prediction is based on the finding by Granqvist & Larsson (2006) that a higher degree of religiousness predicted a higher occurrence of unusual experiences with a religious quality. It follows that participants believing in supernatural concepts more readily interpret random or anomalous mental and physiological events during the God Helmet session as special, sacred or attribute them to a divine agent.

This in turn would cause such events to carry more personal significance and evoke emotional reactions in the subjects. Conversely, participants low in supernatural beliefs are predicted to attribute arising sensations and mental imagery to normal workings of the brain, therefore experiencing less emotions. This hypothesis is in accordance with theories within the cognitive science of religion, which propose that for a given (unusual) event, sensory inputs are evaluated based on prior culture specific knowledge to generate a causal framework explaining the event (Taves & Asprem, 2016).

To account for various arbitrary data processing decisions and ensure transparency of the results, this study employs a multiverse analysis approach (Steegen et al., 2016). This means that analyses are performed on 54 different alternatively processed datasets. Findings of this research this research will contribute to the endeavor of evoking unusual or mystical experiences within an experimental context, thereby paving the way for future studies on unusual experiences such as religious and mystical experiences. Specifically, results of this study will provide insight into the authenticity of reported experiences by assessing a physiological indicator of experience intensity. Consequently, this study contributes to the challenge of aligning objective measures with self-report, which has implications for various fields within psychology relying on self-report data (Dang et al., 2020). The outcomes of this research will provide further evidence for how individual differences affect responses to a placebo manipulation, where measurements are not limited to self-report. By identifying specific personality traits that influence the placebo response, researchers and clinicians can better design studies and tailor treatment plans to maximize positive outcomes (Enck et al. 2013). Furthermore, this research will also provide insight into the strength and weaknesses of novel assessment methods and tools, specifically the use of a continuous response device and fEMG.

Materials and Methods

Participants

In total, 80 English or Dutch-speaking adults were recruited for the experiment. 18 participants were excluded from this study due to: reporting no button presses (9), technical errors (4), fEMG device not recording (3), participant stopping the session (1) and ending up not meeting inclusion criteria (1). For analyses involving corrugator supercilia muscle activity additional 12 participants were removed due to noisy fEMG data (>0.2mV). This resulted in a final sample size of 62 and 50 participants. Descriptive statistics in Table 2 were calculated for the larger sample (N=62). Participants were generally highly educated and of moderate to high social economic status. During recruiting, applicants were excluded if they reported a history of epilepsy, claustrophobia, brain injury, were currently taking medication that might affect emotional functioning, had received Botox injections in the face, or had a history of fainting easily. Recruitment materials were distributed at university faculties, via social media and in meditation and yoga centers, aiming for a heterogenous sample, especially relating to participants' affinity for spirituality.

Considering feasibility constraints, mainly concerning the long session time per participant (3 hours) and the university credits allocated to this project, no further participants were recruited to compensate for the exclusions. A sensitivity analysis using G*Power (Erdfelder et al., 1996) revealed that a one-tailed correlation analysis with an alpha of 0.025, and a power of 0.80 would enable the detection of small-to-medium effect sizes of at least ρ = 0.35 for 62 participants and ρ = 0.38 for 50 participants. Participants received 10 Euro per hour, which resulted in an average compensation of approximately 25 Euro per participant. All participants signed an informed consent form, and the experimental protocol was approved by the local ethics committee.

Table 2

Demographic Information of Participants

Factor	%	Factor	%
Age		SSS	
18-24	37.09	0-20	0
25-34	48.39	20-40	14.51
35-45	14.51	40-60	19.35
Gender		60-80	53.22
Male	58.06	80-100	12.90
Female	40.03		
Education			
Lower	2.09		
Medium	24.19		
Higher	54.83		

Note. N=62, SSS = Subjective Social Status Scale (Adler et al., 1994).

Experimental Design

The driving consideration that informed the design of this study was to increase the frequency and intensity of experiences caused by the placebo brain stimulation. Thus, to maximize credibility while reducing skepticism, the current study implemented an individual difference design, with all participants following the same procedure and receiving the same experimental manipulation. The reason for this is that previous research by van Elk (2015) found that instructions regarding whether the helmet was turned on or off were not effective, and that the mere fact of there being multiple conditions increased skepticism in the participants. Furthermore, as experiments were conducted in a suggestible environment, it is likely that the setting would influence both the helmet on and the helmet off conditions, resulting in a small difference between the two. Additionally, interviewing participants about their experience in the first session would likely influence the experiences in the subsequent session. Lastly, by having no control condition, participants could spend a longer period of time with the God Helmet on, increasing the chance that they would experience something extraordinary (Andersen et al., 2014). The experimental protocol, the procedure, hypotheses and measures were preregistered with the Open Science Framework (https://osf.io/sq4zr).

Expectancy Manipulation

In order to maximize the expectations regarding the God Helmet's potential to induce extraordinary experiences, a combination of environmental/visual cues (Panel A of Figure 2) and written/verbal suggestions were used. As in prior research, a modified motorbike helmet (i. e. the God Helmet) was used to suggest electromagnetic brain stimulation (Panel B of Figure 2; Andersen et al., 2014; Granqvist et al., 2005; Granqvist & Larsson, 2006; Maij et al., 2018; van Elk, 2015; Maij & van Elk, 2018). Three sham electrode cables could be plugged into the outside of the helmet and connected to a sham analog digital-box. The digital-box was modified to appear functional by displaying randomly fluctuating numbers and LED lights that could be turned from red to green using switches. Small speakers were attached to the inside of the helmet to deliver white noise. In the information letter, participants were instructed that they would be subjected to weak electromagnetic fields that stimulated specific regions of their brain, which has previously been shown to evoke a variety of unusual experiences such as visual imagery. To further augment the credibility of the manipulation, the study confirmation email detailed a series of preparatory measures to adhere to prior to arriving at the lab. These measures included abstaining from alcohol consumption for a period of 24 hours, the use of recreational drugs for 7 days, and avoiding food intake for 2 hours preceding the session. Moreover, it was recommended not to schedule any important events after the study as the experiences during the session should be given space to process.

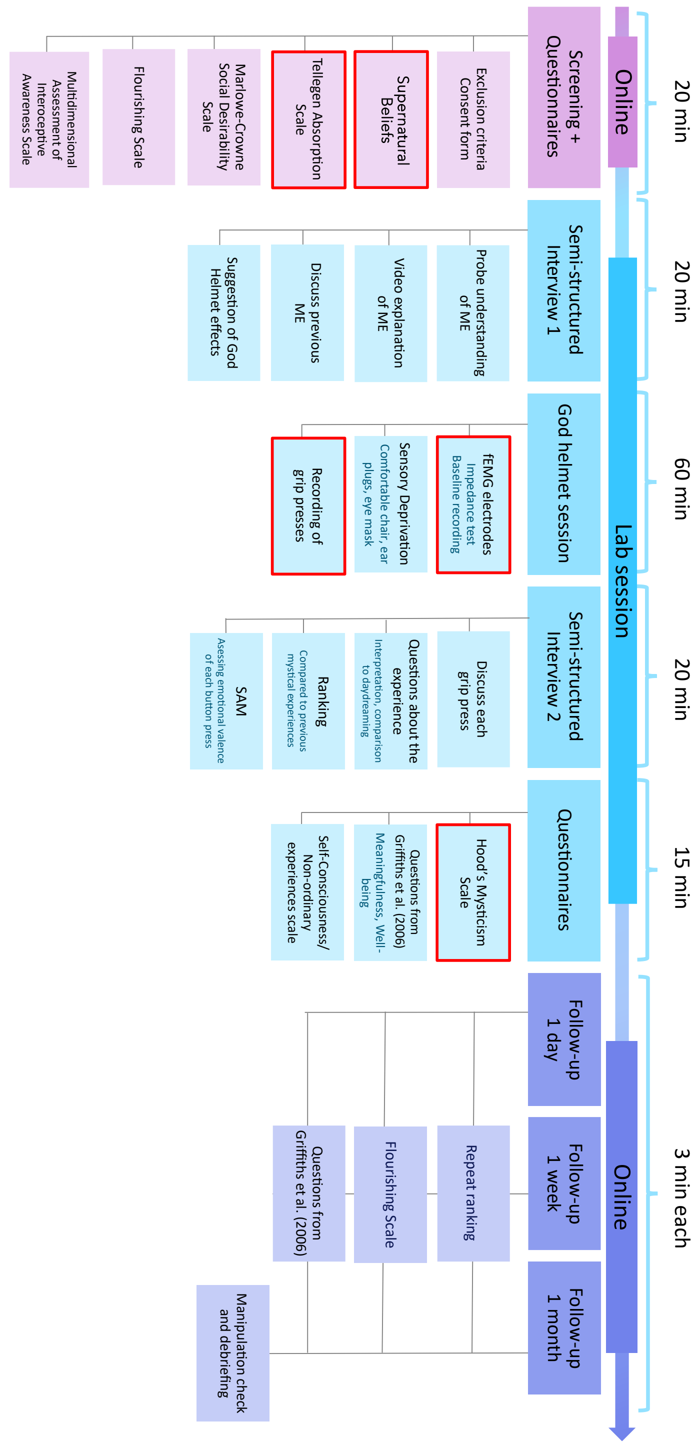
On the day of the experiment, the goal of the study was again verbally repeated and more specific suggestions regarding the types of experiences were given via two videos right before the session. The first video gave an overview of the characteristics of mystical experiences, while the second video included an explanation by Author Steven Kotler on how the God Helmet (supposedly) works (Big Think, 2015) and a report by professor Susan Blackmore on what she experienced when she wore the God Helmet (Web of Stories, 2017). The videos were edited to include the most crucial sections. Lastly, participants were presented with quotes from other God Helmet study participants, reporting visions, body distortions, and strong emotions. To decrease the likelihood of negative experiences, the suggestions mostly included descriptions of positive experiences. Participants were also told that the strength of the stimulation would vary over time. We predicted that this would allow participants to attribute their lack of mystical experience at certain times to the helmet producing weak magnetic fields. In turn, this would increase the expectation for stronger stimulation to come and guard against arising skepticism during the session. To determine the degree to which environmental suggestions, such as decorations and sham laboratory equipment would be used, a pilot survey was conducted (N=45). We decided on an orderly, minimally decorated room with some neuroscience-related equipment. The survey results indicated that such a room was more likely to house legitimate research. Additionally, this environment was found to be conducive to sharing personal experiences. The term "God Helmet" was intentionally excluded throughout the study to prevent potential apprehension among participants who were skeptical of religion. Instead, the helmet was referred to as the Persinger Helmet, named after Michael Persinger, a proponent of the real effects induced by brain stimulation. By using the term "Persinger Helmet," it was more likely that participants would come across viewpoints supporting the potential effects of the helmet during their online searches.

Experimental Procedure and Measures

Given that this project encompassed three distinct master thesis projects, the experimental procedure involved several measures that were not analyzed in this specific thesis. The complete methodology is discussed below and depicted in Figure 1, with measures utilized in this particular thesis highlighted. At the outset of the study, all individuals were directed to an online pre-test, wherein they were presented with an information letter, exclusion criteria and underwent a series of pre-tests which included self-report questionnaires assessing demographics (gender, age, education, SES), prior experience with meditation and psychedelic use, supernatural beliefs (items derived from Lindeman et al., 2019, Appendix A), trait absorption using the Modified Tellegen Absorption Scale (Jamieson, 2005), the extent to which people are aware of their bodily sensations using the Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012) and social desirability using the short version of the Marlowe-Crowne Social Desirability Scale (Strahan & Gerbasi, 1972). Eligible participants were then invited to the lab, where they were picked up at the reception and guided to a laboratory section of the faculty. Participants were asked to leave their phones outside of the testing room (Figure 2, Panel A). Subsequently, participants were given a brief verbal overview of the procedure and instructed to again familiarize themselves with the information letter. Next, participants were shown a video characterizing mystical experiences and asked to elaborate on previous experiences meeting this characterization in a semi-structured interview (Appendix B). fEMG electrodes were placed (Figure 2, Panel B), and another suggestive video was shown while the gel in the electrodes dried. Afterward, participants read an explanation for the use of the response device and the experimenter demonstrated how responses would later be presented as a graph to aid the participants' memory when recalling the experiences. To eliminate sensory distractions, the participant was given an eye mask, optional pillows, and the backrest of the armchair adjusted. The light was dimmed, and the baseline instructions were read to the participant. During the baseline, participants silently counted to 100 while intermittently pressing a grip response device (Figure 2, Panel C) at 20-unit intervals with progressively increasing force. Participants were instructed to indicate the occurrence and intensity of unusual experiences with the placebo God Helmet by pressing this gripper device during the session. Specifically, participants were instructed to squeeze the device once when the unusual experience subsided. The intensity of the experience could be indicated by varying the grip strength applied to the device. The participant was then left alone in a dim room for 45 minutes with white noise playing over speakers in the helmet. During this period, the experimenter was present outside of the experiment room, monitoring a webcam live feed, ready to take action in case of adverse reactions. After the session, participants were interviewed on their experiences and asked to rank the intensity of the experience in comparison with previous mystical experiences. An attempt was made to score the valence of each experience using the Self-Assessment Manikin (SAM; Bradley & Lang, 1994). However, these ratings were not used in the main analysis due to a failure to match subjective ratings of unusual experiences with grip-events. Interviews were conducted in English or Dutch to avoid a bias in responding due to language barriers. Following the interview, participants filled out the 32-item version of the Hood's Mysticism Scale (M-scale; Hood, 1975), an Altered Self-Consciousness Questionnaire (Appendix A), and the 8-item Flourishing Scale (Diener et al., 2010). Lastly, we asked participants to fill in an online questionnaire 1 day, 1 week, and 1 month after the experimental session. This questionnaire included three measures from Griffiths et al. (2006), to assess changes in meaningfulness, spiritual significance, and subjective well-being after the experience at the lab (Appendix A). The last follow-up included a debrief, which explained that the God Helmet had not stimulated participants' brains at any point during the study and described the real purpose of the study.

Figure 1

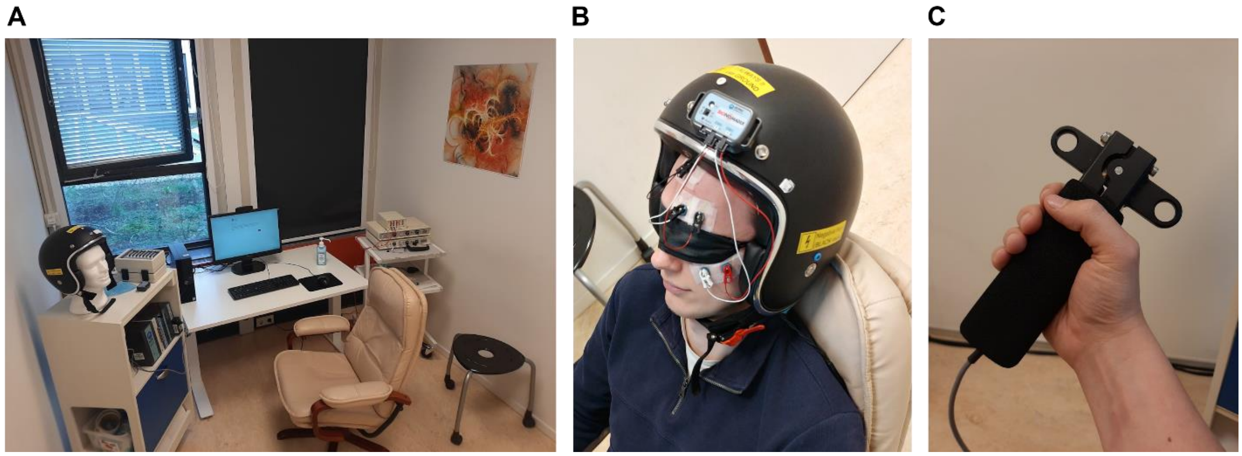
Schematic Diagram of the Study Procedure



Note. Measures utilized in this particular thesis are highlighted in red.

Figure 2

Depiction of the Laboratory Setup and Equipment



Note. Panel A showcases the experimental setting, comprising the God Helmet, a mock amplifier, an armchair, and the fEMG recording equipment. Panel B illustrates the God Helmet in combination with fEMG electrodes. Panel C portrays the grip response device employed by participants to indicate the presence and intensity of unusual experiences.

fEMG Recording

Surface facial electromyography (fEMG) recordings were utilized to assess muscle activity throughout the 45-minute God Helmet session. fEMG allows for the detection and measurement of electrical activity produced by muscle contractions, making it more sensitive to subtle facial expressions than observation or facial mapping software. Importantly, fEMG captures automatic, implicit emotional reactions, which are not susceptible to response bias. fEMG was recorded bipolarly using pairs of standard AG-AgCl electrodes (inter-electrode distance of ca. 20mm) over the corrugator supercilii muscle (“frowning” muscle) and the zygomaticus major muscle (“smiling” muscle) on the left side of the face in accordance with Fridlund and Cacioppo (1986). A ground electrode was placed in the middle of the forehead. A scrub gel (NuPrep) was used to reduce the impedance of the skin and an electrode gel (Signa gel) was used to conduct the electrical signal to the electrode. Electrode contact impedance was checked to be under 10kΩ using the Biopac EL-CHECK electrode checker and where otherwise reapplied. Participants were instructed to refrain from applying any skin products, as this could increase impedance and affect the quality of the signal. To avoid movement artifacts, the electrodes were fixated using masking tape. The signals were recorded and amplified using a wireless BioNomadix/Biopac system (2000Hz) attached to the God Helmet using Velcro. The raw signals were then pre-processed using the EMG Signal Analyzer of the PhysioData Toolbox (Sjak-Shie, 2022). This involved a 30 Hz high-pass filter (to remove blink artifacts and slow signal drifts), a 500 Hz low-pass FIR filter, and a 50 Hz notch filter (to reduce powerline artifacts). The signal was further smoothed using a Boxcar filter (window size 100ms). To minimize the potential for participants self-monitoring their facial expressions, we employed a deception strategy by informing participants that the objective of the electrodes was to assess sweat gland activity. After the experiment, participants were informed about the true purpose of the measurement.

Multiverse Approach for Data Processing

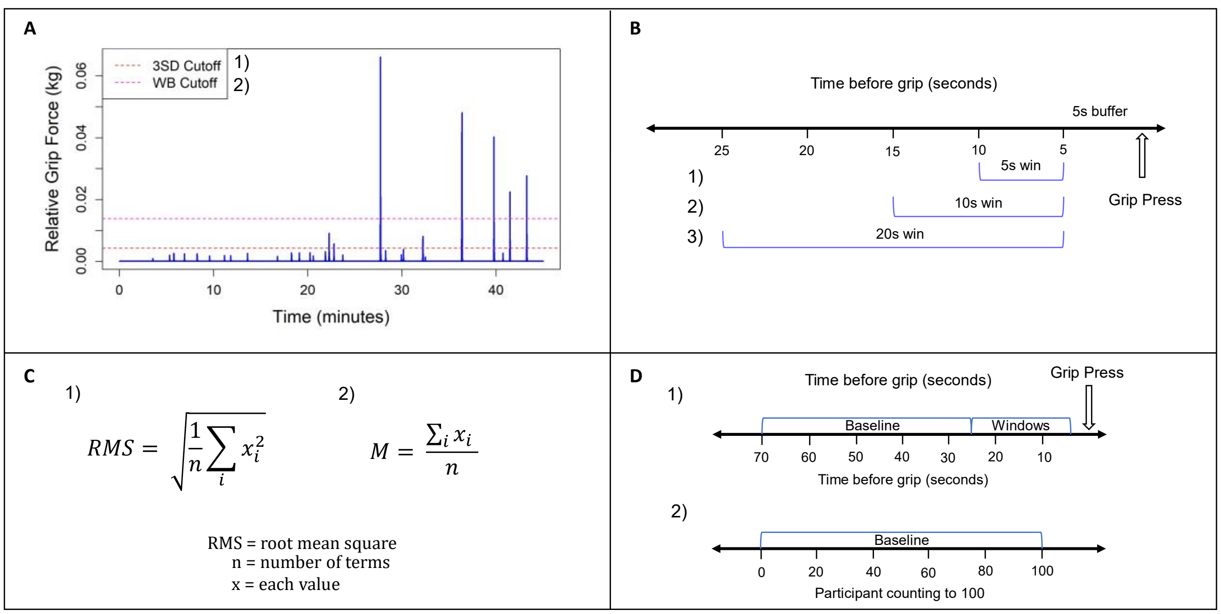
Due to the unique study design, several data processing stages involved arbitrary decisions that could hypothetically diverge if implemented by another research team, resulting in many researcher degrees of freedom (Simmons et al., 2011). To make the influence of different decisions during data processing transparent, a multiverse analysis approach was used (Steegen et al., 2016). Thus, analyses were performed on multiple alternatively processed datasets, providing a more detailed picture of the robustness or fragility of statistical results. Data processing and analysis were performed using the statistical software R (Version 4.1.3; R Core Team, 2022). The "multiverse" package (Sarma et al., 2021) facilitated the execution of multiverse analysis, while mixed models were fitted using the "lme4" package (Bates et al., 2015). The "nlme" package (Pinheiro, 2022) was utilized to derive *p* values for the mixed models. It follows a description of the processing decisions for this data.

Initially, fEMG baseline and experiment recordings were normalized within participants, as the range of activity can vary strongly between individuals (Lang et al., 1993; Larsen et al., 2003). Therefore, all reported muscle activity should be interpreted as scaled values ranging between 0 and 1. Time points at which unusual experiences occurred were determined by analyzing the gripper response device data and identifying peaks, representing grip-events. The grip data was strongly filtered using a 0.3 Hz high-pass and low-pass filters and squared to enlarge strong grips and shrink weaker grips. Subsequently, three different methods were used to select grip-events (Parameter A, Figure 3): Grip-events falling three standard deviations above the overall mean activity (3SD); grip-events stronger than the weakest of the five baseline presses of that individual (WB); the four strongest grip-events (Strongest 4). Analysis paths using the weakest baseline threshold method contained fewer participants (zygomaticus N = 31; corrugator N = 24) as some participants did not surpass this threshold with their grip presses. The third criterion was based on the fact that, on average, participants reported four notable events during interviews conducted immediately after the session. Next, for the determined grip-events of each participant, the associated fEMG data was extracted. Again, three possible decisions for the selection of a time window were included in the multiverse (Parameter B,

Figure 3): The 20 seconds preceding a grip event (20s before); the 10 seconds preceding a grip event (10s before); the 5 seconds preceding a grip event (5s before). Plotting the fEMG data during baseline revealed an influence of the grip action on facial muscle activity, thus a four-second buffer period was inserted between the grip-events and the extracted windows. Next, the absolute mean (M) or the root-mean-squared (RMS) of the fEMG data within each time-window was calculated (Parameter C, Figure 3). Finally, the resulting scores were baseline corrected (Parameter D, Figure 3) by subtracting the mean activity during the separately recorded baseline task (BC1), or baseline corrected by subtracting the mean activity during the 45 seconds preceding the time window (BC2), or not baseline corrected (no BC). To represent the strength of an emotional response, all scores were converted into absolute values, which corresponded to the deviation from baseline activity. This resulted in (A) 3 x (B) 3 x (C) 2 x (D) 3 = 54 differently pre-processed datasets to perform the analysis on.

Figure 3

Visualization of the four parameters in the multiverse analysis



Note. Panel A shows the two threshold methods for selecting grip-events (1,2). Panel B displays the three fEMG data window sizes used in the analysis (1,2,3). Panel C illustrates two methods for quantifying fEMG data within a given window (1,2). Panel D presents two methods to obtain baseline scores (1,2).

Statistical Analysis

As fEMG scores during unusual experiences were nested within participants, mixed models were used to account for the hierarchical structure of the data. Mixed models allow the relationship between dependent and independent variables to vary by individual and thus account for potentially correlated observations within a participant due to repeated testing and different number of observations per participant (Snijders & Bosker, 1999). The dependencies within one subject were corrected for by including a random factor for participants, allowing varying intercepts per participant. While the mixed models were planned to include random slops, this addition was dropped due to the model being overfitted – that is, the random effects structure was too complex to be supported by the data in many universes. Upon detecting multiple violations of the model assumptions, including linearity, homogeneity of variance, and normal distribution of residuals, data transformations (log10 and square root) were implemented. However, these transformations were not adopted in the analysis as they were ineffective in resolving the assumption violations. Instead, additional post-hoc non-parametric tests were performed.

To test whether participants' emotional responses were stronger during unusual experiences than during time-windows not relating to grip-events (Hypothesis 1), time-windows not relating to grip-events were generated by randomly selecting time-windows during the 45 minutes session, which were of the same length- but did not overlap with grip-related time-windows. Every participant therefore had grip-related fEMG scores and the same number of fEMG scores calculated over time-windows not relating to grip-events. Using a mixed-model, fEMG scores were then predicted by a dummy variable indicating whether a score stemmed from a grip-event related time-window or not. Additionally, a Wilcoxon signed-rank test was performed on the median values of real and random fEMG data.

Further, to establish whether the strength of the emotional responses was associated with the grip strength applied to the response device (Hypothesis 2), grip strength was predicted by fEMG scores using a mixed model. Here, grip strength represents a relative value, calculated by dividing the current grip strength by the strongest grip during the baseline of that individual. Kendall's tau-b rank correlation coefficients were correlated between grip strength and fEMG scores (for each multiverse dataset).

To investigate the relationships between absorption, M-Scale scores, and emotional responses (Hypothesis 3), and the relationship between supernatural beliefs and emotional responses (Hypothesis 4), one mixed model was fitted, predicting fEMG scores by absorption, supernatural beliefs, and M-Scale scores. Additionally, post-hoc non-parametric analyses were performed, calculating the Kendall's tau-b rank correlation coefficient between questionnaire scores and fEMG activity.

For all hypotheses, the analysis was repeated once using fEMG zygomaticus major activity and once with corrugator supercilii activity. By performing two analyses per hypothesis, the chance to find support for the hypothesis was doubled. To compensate for this increased chance of Type 1 errors, a Bonferroni correction was applied, resulting in a p-value of 0.025. Based on unforeseen data characteristics, some deviations from the pre-registration plan were deemed necessary in the course of the study. A comprehensive account of the specific deviations can be found in Appendix C.

Results

The current study investigated four hypotheses related to emotional responses, grip response strength, and self-report measures associated with unusual experiences. To obtain an overview of the measures used in the study, Table 3 summarizes the mean scores, standard deviations and correlations of the relevant questionnaire scores and grip event counts. Positive correlations were found between Supernatural Beliefs scores and Absorption scores; M-Scale scores and Absorption scores; and grip event counts using the three standard deviation method and grip event counts using the weakest baseline approach.

Table 3

Summary Statistics and Correlations

Variable	*M*	*SD*	1	2	3	4	5	6	7
1. Absorption	3.32	0.71	—						
2. Supernatural Beliefs	2.96	0.95	0.59**	—					
3. M-Scale	2.46	0.79	0.32*	0.45**	—				
4. Grips 3SD	14.61	9.45	0.02	-0.12	0.14	—			
5. Grips WB	3.98	7.12	0.07	-0.07	-0.05	0.55**	—		
6. Social Desirability	3.19	0.53	0.21	0.16	-0.02	0.05	-0.07	—	
7. SAM	6.18	1.62	0.14	0.02	0.27	0.01	-0.06	-0.11	—

Note. N =62. * indicates $p < 0.05$. ** indicates $p < 0.01$. Questionnaires range between 1-5, except the SAM (Self-Assessment Manikin), which assesses valence on arrange of 1-10 with 10 being the most positive. *M* and *SD* represent mean and standard deviation. Grips 3SD refers to the number of grip-events obtained using a 3 standard deviation above the mean threshold. Similarly, Grips WB refers to grip event counts obtained using the weakest baseline press as threshold.

The internal consistency of scales was assessed using Cronbach's α: Modified Tellegen Absorption Scale (α = .93), the Marlowe-Crowne Social Desirability Scale (α = .68), supernatural beliefs (α = .92), and the M-Scale (α = .96). The coefficients indicated good to excellent internal consistency for most scales meaning that the scales were generally reliable measures of their respective constructs, although caution should be exercised when interpreting scores on the Social Desirability Scale. To check whether the placebo manipulation was successful, we asked participants one month after the session whether they thought that the God Helmet had actually stimulated their brain, to which 64.4% answered positively. Further, we asked whether participants believed that the God Helmet was capable of inducing mystical experiences, to which 71.18% agreed. Finally, 33.89% of participants believed that they were deceived in some way during the study.

Despite the violations of assumptions in the mixed regression analyses, the fixed effects estimates, confidence intervals, and *p* values were still reported, as the model was originally anticipated in the pre-registered statistical analysis plan. The adequacy of p-values as indicators of statistical significance in mixed models is subject to ongoing debate (Luke, 2016). As such, in addition to providing p-values, I also present the number of analysis paths that yield coefficients with a confidence interval that excludes the null hypothesis of zero effect. Intra-class correlations (ICC) and effect sizes of the mixed regression models are omitted due to the bad model fit. Instead, I also present the findings from post-hoc non-parametric tests that were conducted as a result of poor model fit. The results of non-parametric results tend to be more liberal across all hypotheses. When interpreting results, it is important to consider that fEMG recordings were normalized within participants to a range of 0 to 1.

Hypothesis 1

Regarding the first hypothesis, predicting that participants' emotional responses are stronger during unusual experiences than during randomly chosen time windows, the mixed regression models reveal little evidence for a difference in absolute zygomaticus major and corrugator supercilii activity. The p-values of mixed regression models are shown in Panels A and B of Figure D1 and appear spread randomly between 0 and 1. Even though up to 11.11% of analysis paths show a significant effect, the effect is practically zero (all fixed effects estimates below 0.01) and we can say so with good certainty (all CI intervals smaller than 0.01). A small number (5.56%) of post-hoc non-parametric tests suggest an increase in absolute corrugator response in gripper-related windows. Similarly, some post-hoc analyses indicate increases in zygomaticus responses (7.41% significant analysis paths; Table 4). Based on guidelines by Rosenthal et al. (1994), there is a medium to large effect size ($r = 0.38$) for a corrugator response increase and a medium effect size ($r = 0.31$) for zygomaticus response increase. The p-values of post-hoc analyses are shown in Panels A and B of Figure 4 and appear spread randomly.

Hypothesis 2

For the second hypothesis, predicting that emotional responses during unusual experiences are associated with the corresponding grip strength used to indicate the intensity of unusual experiences, negligible evidence supporting this claim was found based on the mixed regression models (Table 4 and Figure D1: Panel C and D). The effect is practically zero (all fixed effects estimates below 0.01) and we can say so with good certainty (all CI intervals smaller than 0.01). However, in a post-hoc analysis with a different statistical model, 18.52% of the analysis paths resulted in significant but weak positive relationships between grip strength and zygomaticus activity (average tau-b of significant universes: 0.05) and 16.67% of the analysis paths resulted in positive associations between grip strength and corrugator activity (average tau-b of significant universes: 0.14). The p-values of post-hoc analyses are shown in Panels C and D of Figure 4 and appear spread randomly for the zygomaticus muscle and with some tendency for small p-values for the corrugator.

Table 4

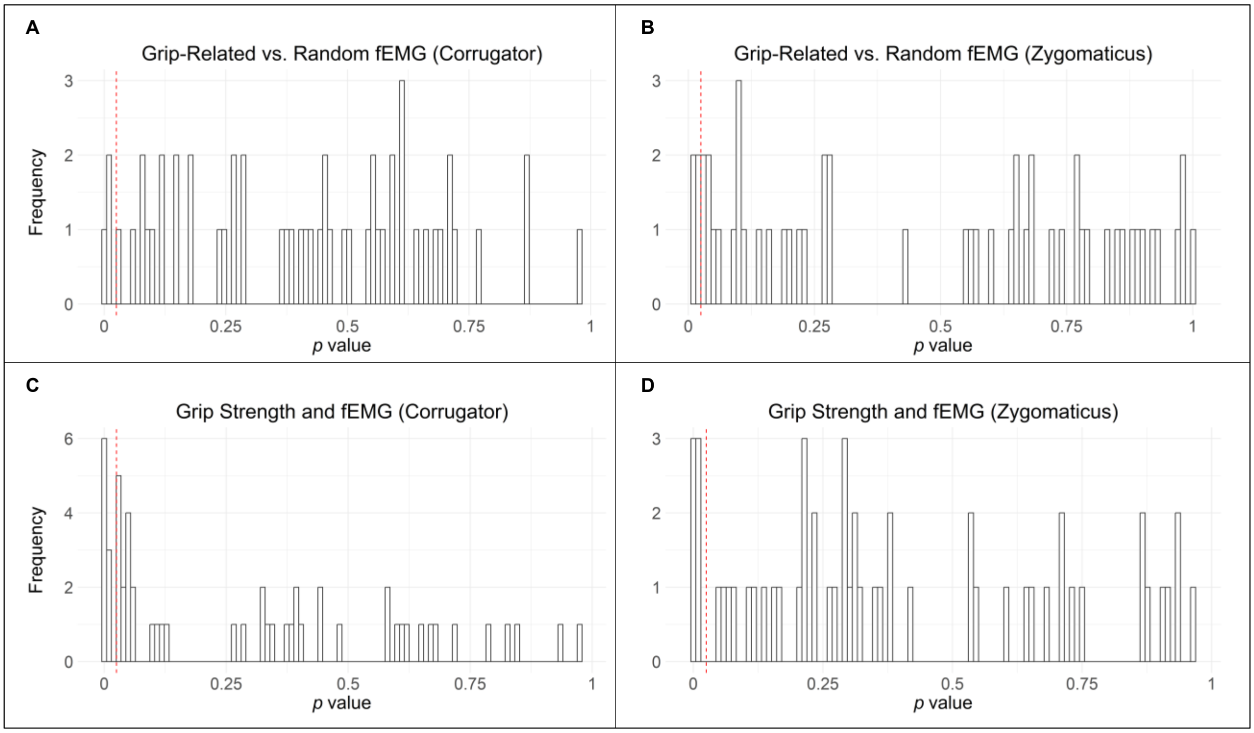
Multiverse Analysis Results: P values, Confidence Intervals, and Post-hoc Analysis Findings

Predictors	Significant analysis paths out of 54 (zygomaticus)			Significant analysis paths out of 54 (corrugator)		
	p	CI	NP	*p*	CI	NP
HP1: Grip event related vs random	1 (0.02%)	6 (11.11%)	4 (7.41%)	2 (3.7%)	6 (11.11%)	3 (5.56%)
HP2: Grip strength	0	0	10 (18.52%)	0	3 (5.56%)	9 (16.67%)
HP3: Absorption	6 (11.11%)	10 (18.52%)	33 (61.11%)	6 (11.11%)	6 (11.11%)	24 (44.44%)
HP3: M-Scale	0	0	2 (3.7%)	10 (18.52%)	15 (27.78%)	39 (72.22%)
HP4: Supernatural Beliefs	0	0	15 (27.78%)	0	8 (14.81%)	38 (70.37%)

Note. The results are presented as significant according to: *p* value (*p*) / confidence interval (CI) / non-parametric (NP). It follows the respective percentage (of 54 analysis paths) in brackets.

Figure 4

Distributions of p Values From 54 Post-Hoc Analyses Conducted for Hypotheses 1 and 2



Note. The red dotted line indicates $p = 0.025$. Panels A and B refer the results of the mixed regression model results for the first hypothesis. Panels C and D refer to the second hypothesis.

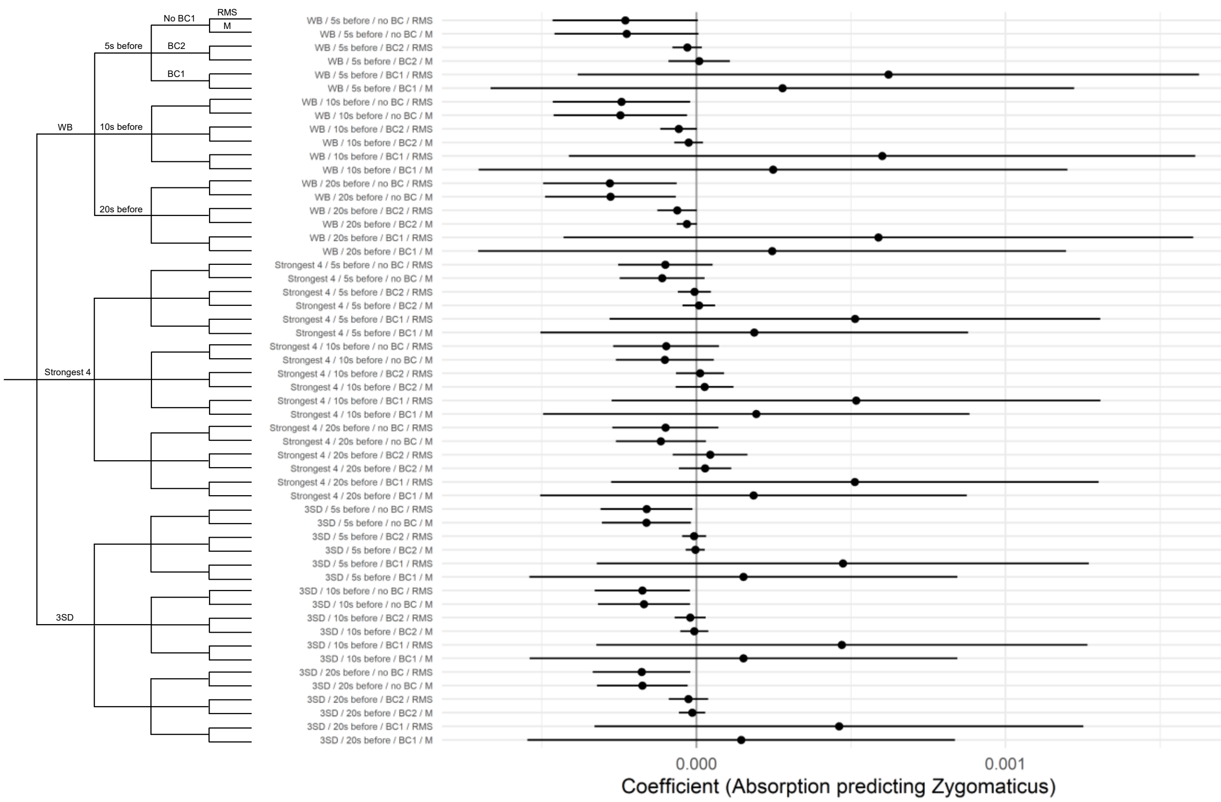
Summarizing findings from Hypothesis 1 and 2, mixed regression models provide very limited evidence for both analyses, with a small amount of significant analysis paths and small effects. While post-hoc analyses indicate moderate effect sizes for increased emotional responses during unusual experiences, these results are not consistent across analysis paths. Associations between emotional responses and grip strength are weak and not consistent across analysis paths.

Hypothesis 3

Some support was found for the third hypothesis, positing that self-report measures previously associated with unusual experiences during a God Helmet session (Absorption and M-Scale) would predict emotional responses (Table 4). The few significant analysis paths (18.52% for zygomaticus and 11.11% for corrugator) result in small negative fixed effects estimates, indicating that absorption predicts a reduced zygomaticus and corrugator response. The effect, however, is close to zero (all fixed effects estimates below 0.01) and we can say so with good certainty (all CI intervals smaller than 0.01; Figure 5). Coefficient graphs are not included for all hypotheses and muscles as effects are generally small. In Figure 5 it becomes apparent that the analysis paths using the separately recorded baseline for baseline correction (BC1) result in larger confidence intervals and opposite (although insignificant) effects. One possible reason for this could be that the standard deviations of fEMG scores within this pre-processing path are significantly higher compared to other baseline correction methods. While this baseline correction method seems to add noise, it was retained in the multiverse to provide transparency and insight into the impact of the baseline correction method. The distribution of *p* values across analysis paths appears largely random, potentially skewed towards small *p* values for the zygomaticus muscle (Figure D2, Panel A and B)

Figure 5

Absorption's Impact on Zygomaticus Response: Fixed Effects Coefficients across Multiverse

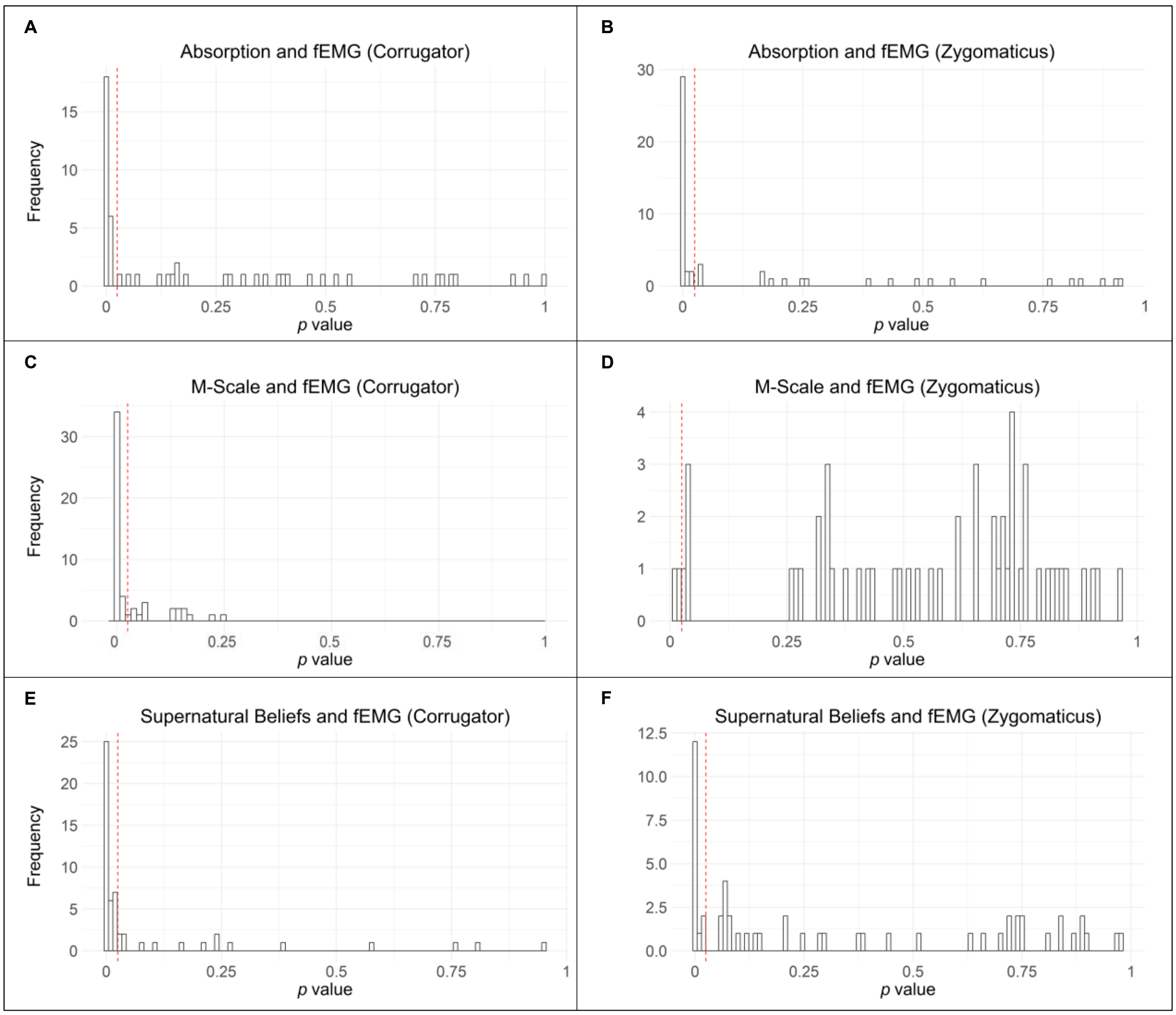


Note. Results of mixed regression analysis. Each node in the branching diagram on the Y-axis represents a processing step with several reasonable alternatives. Abbreviations: WB = weakest baseline threshold, 3SD = 3 standard deviation threshold, BC1 = baseline correction using separately recorded baseline, BC2 = baseline correction using a 45-second window before grip-events, no BC = no baseline correction, M = Mean, RMS = Root-Mean-Square. Analysis paths using the weakest baseline threshold method contain fewer participants (zygomaticus N = 31; corrugator N = 24). Note that fEMG activity is normalized between 0 and 1. Effect of absorption on fEMG is negligible according to mixed effects analysis.

The post-hoc non-parametric tests are again more liberal, resulting in a larger number of significant effects across analysis paths. Across analysis paths, 44.44% resulted in significant small negative correlations between corrugator response and absorption, while 61.11% exhibited a significant small negative correlation between zygomaticus response and absorption (average tau-b of significant universes: zygomaticus -0.14 and corrugator -0.15). The distribution of *p* values across analysis paths includes many small *p* values, however other values appear randomly distributed (Figure 6, Panel A and B).

Figure 6

Distributions of p Values From 54 Post-Hoc Analyses Conducted for Hypotheses 3 and 4

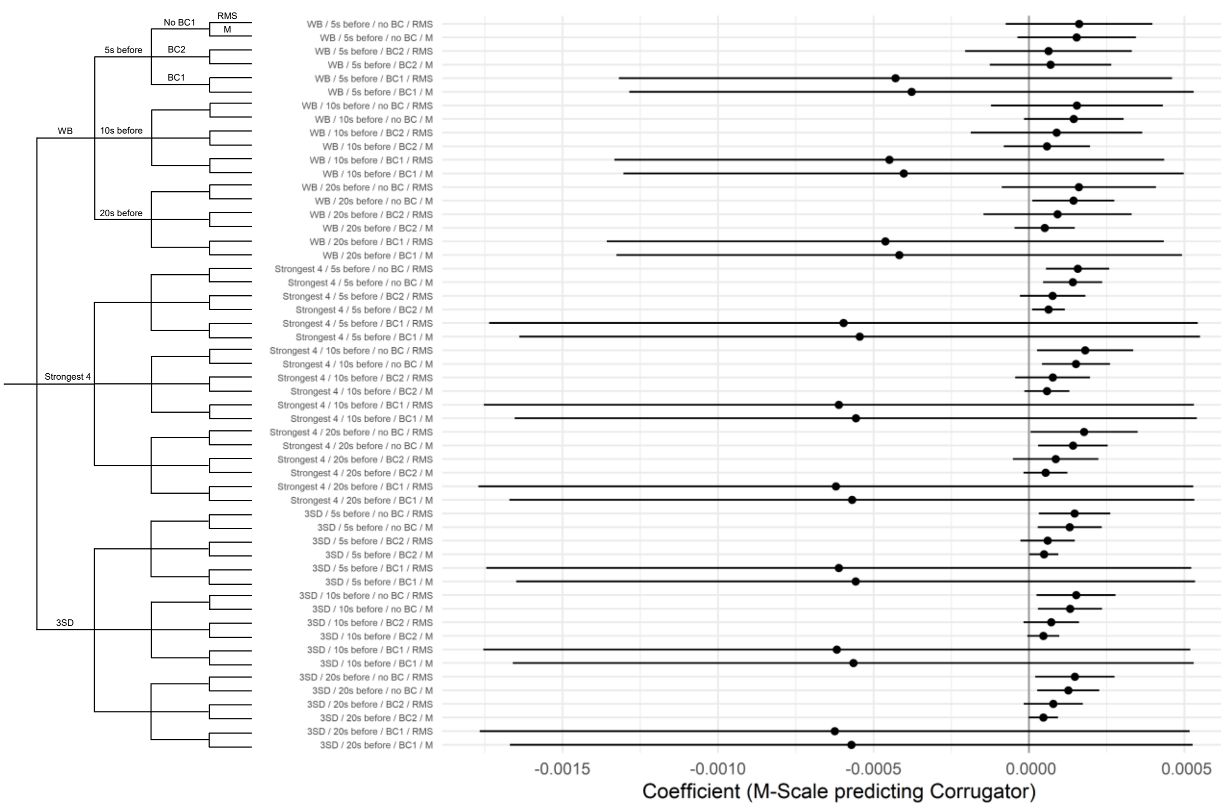


Note. The red dotted line indicates p = 0.025. Total analysis paths = 54. Panels A, B, C and D refer the results of the mixed regression model results for the second hypothesis. Panels E and F refer to the fourth hypothesis.

M-Scale scores appear somewhat consistently predictive of higher corrugator response, while there does not seem to be a relationship with zygomaticus response. The effect, however, is close to zero (all fixed effects estimates below 0.01) and we can say so with good certainty (all CI intervals smaller than 0.01; Figure 7). Analysis paths using the first baseline correction method show a reversed, although insignificant pattern. The distribution of *p* values across analysis paths appears largely random, potentially skewed towards small *p* values for the corrugator muscle (Figure D2, Panel C and D). Based on post-hoc analyses, M-Scale scores are found to be weakly positively correlated with corrugator response across 72.22% of the analysis paths and inconsistently negatively correlated with zygomaticus response in 3.7% of the analysis paths. Correlation coefficients are, however, small to negligible (average tau-b of significant universes: corrugator 0.09 and zygomaticus -0.06). The distribution of *p* values across post-hoc analysis paths appears strongly right skewed for the corrugator and random for the zygomaticus (Figure 6, Panel C and D).

Figure 7

M-Scale's Impact on Zygomaticus Response: Fixed Effects Coefficients across Multiverse



Note. Results of mixed regression analysis. Each node in the branching diagram on the Y-axis represents a processing step with several reasonable alternatives. Abbreviations: WB = weakest baseline threshold, 3SD = 3 standard deviation threshold, BC1 = baseline correction using separately recorded baseline, BC2 = baseline correction using a 45-second window before grip-events, no BC = no baseline correction, M = Mean, RMS = Root-Mean-Square. Analysis paths using the weakest baseline threshold method contain less participants (zygomaticus N = 31; corrugator N = 24). Note that fEMG activity is normalized between 0 and 1. Effect of M-Scale scores on fEMG is negligible according to mixed effects analysis.

Hypothesis 4

Regarding the fourth hypothesis, the regression models offer little support for a relationship between supernatural belief scores and fEMG activity (Table 4). There is some limited evidence across 14.81% analysis paths for increases in corrugator response. Effects are, however, close to zero (all fixed effects estimates below 0.01) and we can say so with good certainty (all CI intervals smaller than 0.01). The distribution of p values across analysis paths appears largely random (Figure D2, Panel E and F). Post-hoc analyses reveal moderate negative correlations between supernatural belief scores and zygomaticus response (tau-b = -0.17) across 27.78% of paths, as well as weak to negligible positive correlations with corrugator response (tau-b = 0.04) across 70.37% of analysis paths. The distribution of p values across post-hoc analysis paths show many small *p* values, however other *p* values appear randomly distributed (Figure 6, Panel E and F).

To summarize, the evidence base for hypotheses 3 and 4 is slightly stronger in comparison to hypotheses 1 and 2. However, the mixed regression models again provide negligible evidence, with some support from post-hoc analyses: Across analysis paths, there is quite consistent results indicating a weak negative relationship between emotional responses in both muscles and absorption. There is a consistent finding of a mild increase in corrugator response among individuals who score high on the M-Scale. Lastly, post-hoc results reveal some indications of decreased zygomaticus response (inconsistent across analysis paths) and increased corrugator response (consistent across analysis paths) among participants scoring high on supernatural beliefs. Next, I present results of an exploratory analysis on a subset of participants, followed by exploring the subjective valence ratings and directionality of fEMG responses.

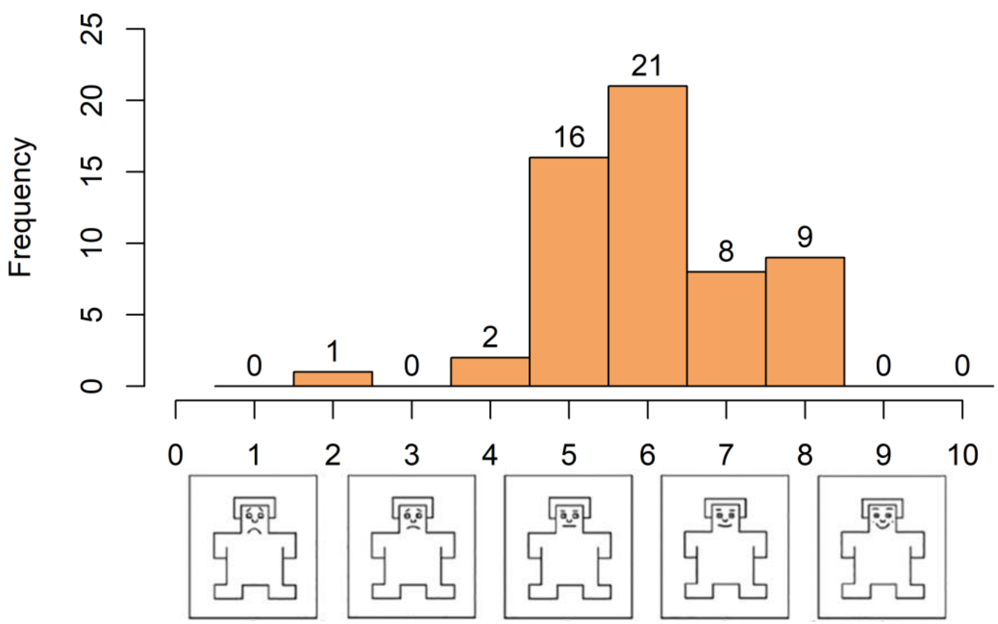
Exploratory Analyses

All the aforementioned hypotheses were also applied to a subset of participants who believed that the helmet was capable of inducing mystical experiences. Results of the mixed models were similar to previous results, in that they provided little evidence for any of the hypotheses. However, some notable deviations in non-parametric test results were found. There was an increase from 3.7% to 42.59% in significant positive correlations between zygomaticus activity and M-Scale scores (tau-b change from -0.06 to 0.18). Furthermore, there was an increase from 22.22% to 40.07% significant correlations between zygomaticus response and supernatural beliefs (tau-b increase from 0.15 to 0.27). However, the correlation between reduced corrugator activity and supernatural beliefs appeared to be less consistent, with 29.62% of significant analysis paths compared to the previously reported 48.14% (tau-b increase from -0.12 to -0.2).

As discussed in the methods, subjective valence ratings using the SAM were not used in the main analysis due to a failure to match subjective ratings of unusual experiences with grip-events. Additionally, an unknown number of responses with a score of 5 were lost. On average, 3.82 responses per person were retained, which is similar to the number of unusual experiences gathered through threshold and counting methods (4), thus indicating a minimal loss of data. An exploratory analysis of this data revealed slightly positive valence ratings on average (M = 6.18, SD = 1.62, range = 1-10). 72.57% of unusual events were assigned positive valence ratings (above 5), while a considerably smaller fraction of 13.5% was associated with negative evaluations (below 5). The distribution of average scores per participant is also strongly skewed to the left, as portrayed in Figure 8.

Figure 8

Distribution of Average Subjective Valence Ratings per Person



Note. A score of 0 represents strongly negative valence, while a score of 5 represents neutral valence, and a score of 10 strongly positive valence.

Lastly, previous analyses were performed on the absolute deviation of baseline fEMG. In the event that half of the participants felt positive emotions and the remaining half experienced negative emotions, the signal would negate itself. To check whether this was the case and to further explore the direction of emotional valence during the experiences, all analyses were also performed on non-absolute fEMG window scores, now representing inhibited or increased activity instead of an overall deviation from baseline. Results of the mixed models were similar to previous results, in that they provided little evidence for any of the hypotheses. However, some notable deviations in non-parametric test results were found: Results of some analysis paths (22.22%) suggest an increase in corrugator activity with increasing grip strength (tau-b = 0.15). Close to half of all datasets (44.44%) support a negative relationship between corrugator activity and absorption (tau-b = -0.12). A similar number of datasets (38.89%) support the same relationship with zygomaticus activity (tau-b = -0.17). These results align with the main analysis. More than half datasets (55.56%) suggest increased corrugator activity in individuals scoring highly on the M-Scale (tau-b = 0.17). Individuals high in supernatural beliefs appear to have increased zygomaticus activity (tau-b = 0.15) in 22.22% of datasets and inhibited corrugator activity (tau-b = -0.12) in 48.15% datasets.

In summary, exploratory analyses provided several insights: Among participants believing in the God Helmet suggestions a stronger association between zygomaticus response and both M-Scales scores and supernatural beliefs was observed. Across all participants, few experiences were rated negatively, with positive experiences being five times more prominent than negative experiences. Analyses on non-absolute fEMG scores suggest increased frowning in individuals scoring highly on the M-Scale, while individuals high on supernatural beliefs smile more and frown less.

Discussion

The objective of this research was to examine physiological responses during placebo-induced unusual experiences and to compare them to self-reported occurrences and intensity of the experiences. The absence of physiological measures in similar previous studies has left room for results to be affected by response bias, especially due to social desirability. Secondly, this study aimed to investigate the link between physiological responses during unusual experiences and individual differences, such as reported levels of absorption, supernatural beliefs and mystical qualities of the experience.

Results of the pre-registered main analysis did not provide substantial evidence in favor of any of the proposed hypotheses, with small numbers of significant analysis paths and small effects. Due to a poor fit of this initial model, I focus on results of post-hoc analyses utilizing different statistical models. A moderate effect for increased emotional responses during unusual experiences was found. However, these findings were not consistent across analysis paths (HP1). Results indicated weak associations between self-rated experience intensity and emotional responses are weak, which were again not consistent across analysis paths (HP2). A large portion of the analysis paths indicated a weak negative relationship between emotional responses in both muscles and absorption (HP3). Also consistent across analysis paths, findings suggested a mild increase in corrugator response among individuals who scored high on the M-Scale (HP3). Post-hoc results further revealed weak indications of decreased zygomaticus response (inconsistent across analysis paths) among participants scoring high on supernatural beliefs (HP4). In the following, I will discuss these results in the context of existing literature and suggest insights and interpretations. Subsequently, I will address how this study contributes to this line of research and assess the strengths and limitations of the study. Lastly, I will make suggestions for future research.

Regarding the first hypothesis, findings provided limited evidence that corrugator (frowning) and zygomaticus muscle (smiling) responses were different during unusual experiences, when compared to randomly selected periods. These results indicated that participants did not consistently exhibit physiological responses associated with emotional reactions during unusual experiences, which appeared to be contradictory to self-reports of emotional experiences in this study and in earlier studies (Maij et al, 2019; Maij & van Elk, 2018; van Elk, 2015). One explanation for the absence of measurable emotional responses is that the experiences were not consistently or sufficiently unusual, therefore eliciting limited emotions in participants. This notion is supported by a low average M-Scale score, where the average participant leans towards disagreement or neutrality in regard to having had an experience with mystical qualities. The absence of measurable emotional responses during unusual experiences could also be linked to the engagement of higher cognitive mechanisms rather than emotional processes. In other words, experiences with the God Helmet could be internalized and not outwardly manifested. This notion finds support in neurophysiological research on religious practices (Azari et al., 2001) and meditation (Newberg & Iversen, 2003), which suggests the involvement of cortical regions related to higher cognitive and attentional functions. However, as discussed earlier, emotion-related neural substrates have also been shown to be involved in such experiences (McNamara, 2014). Another explanation concerns the variation in introspective abilities across individuals (Fleming et al., 2010), which might lead to instances of overlooking certain experiences or mistiming the report. Resulting temporal lag between the subjective experience and objective measurement could result in a weak association between the two.

Secondly, the study yielded little evidence supporting a link between the strength of emotional responses during unusual experiences and the corresponding grip strength used to indicate the intensity of unusual experiences. It is intriguing that experiences reported to be strongly unusual did not evoke heightened emotional responses. Possible explanations behind this finding correspond to aforementioned aspects: mild unusual experiences, a lack of external manifestations of internal experiences or limited introspective capabilities leading to mistiming the report or forgetting to report some experiences. While one has to consider the alternative explanations outlined above and the limitations of the study discussed below, the observed discrepancy between self-report and objective measure raises uncertainties on the reliability of self-reports and, consequently, the authenticity of reported experiences.

While I predicted that individuals more likely to become absorbed in their experiences would have stronger emotional responses, the results indicated the opposite, with overall less absolute corrugator and zygomaticus response during unusual experiences. Absorption has consistently emerged as a reliable measure in predicting the intensity and frequency of experiences with the God Helmet (Maij & van Elk, 2018), which is partly supported by findings in this study, where absorption is linked with scores on the M-Scale (but not with the frequency of unusual experiences). It is surprising that the connection between absorption and the intensity of experiences does not translate into heightened emotional responses. This is surprising because reduced emotions typically indicate a disconnection from the experience, which contradicts the understanding of absorption as a state of “total attention involving a full commitment of available perceptual, motoric, imaginative and ideational resources to a unified representation of the attentional object” (Tellegen & Atkinson, 1974, p. 274). It is possible that individuals with higher absorption tendencies internalize their experiences rather than expressing them outwardly or experience heightened relaxation during the study, resulting in dampened emotional responses and more relaxed facial muscles.

Moreover, some evidence suggests a tendency for increased corrugator activity in participants with higher M-Scale scores. It is reasonable to expect stronger emotional reactions among participants who attribute more mystical qualities to their unusual experiences. However, increased frowning, often associated with negative valence (Larsen et al., 2003) is intriguing given the classic portrayal of mystical experiences as pleasurable, ecstatic or otherwise positive (Stace, 1960; Hood, 1975; Saver & Rabin, 1997). However, this notion has been critiqued to be too simplistic, as emotions like anxiety or fear have been reported during mystical experiences

(Bradford, 2013). Contrary to this explanation, self-reported valence is skewed towards positive emotions. In general, this evidence for emotional responses consistent with participants' self-reported mysticism provides support for the genuine nature of the experiences.

Lastly, while results are mixed, post-hoc findings endorse an inhibition of corrugator activity and a potential increase in zygomaticus activity in individuals holding strong supernatural beliefs. These results suggest that individuals who hold supernatural beliefs tend to have more positive experiences with the God Helmet. One possible explanation of this finding is that religious schemas are more prevalent and active in these participants (Pargament 1997, as cited in Granqvist & Larsson, 2006), causing random or anomalous mental and physiological events during the God Helmet session to be perceived as special, sacred or ascribed to a divine agent by these participants. However, self-rated valence is not associated with supernatural beliefs, demonstrating another dissociation between objective and self-report measures. On the other hand, supernatural beliefs were found to be correlated with M-Scale scores, supporting the notion that participants believing in the supernatural are more likely to attribute grand causes to anomalous events during the God Helmet session.

Exploratory analysis results indicate that few experiences were rated negatively, with positive experiences being five times more prominent than negative experiences. This is not surprising given that suggestions mostly included descriptions of positive experiences to decrease the likelihood of adverse events. Further, exploratory findings support stronger associations between zygomaticus response and both M-Scale scores and supernatural beliefs in subjects believing the God Helmet suggestion. These findings could be interpreted in that the suggestions led to stronger placebo effects in these participants, causing stronger mystical experiences.

Zooming out, this research advances previous studies by employing a physiological measurement during unusual experiences with the God Helmet for the first time and utilizing a novel response-device, allowing participants to indicate the intensity of their experiences on a continuous spectrum. This study supports previous findings of subjective reports of unusual experiences during placebo brain-stimulation and sensory deprivation, although not consistently mystical. The failure to find physiological counterparts to reported occurrences and intensities of unusual experiences raises uncertainties about the authenticity of the experiences and underscores the potential of biased reporting, as discussed in the introduction. However, several limitations and alternative explanations have to be considered. It is also crucial to recognize that the lack of evidence for a relationship between measures does not confirm the absence of such a relationship. Additionally, the presented evidence for emotional responses consistent with participants' self-reported mysticism provides support for the genuine nature of the experiences. This finding also endorses the possibility of evoking mystical experiences in the context of the lab (Andersen et al., 2014).

Several strengths and weaknesses of this study's methodology should be considered when interpreting the results. In terms of generalizability, the sample of this study was non-random, consisting mainly of young, highly educated individuals with relatively high subjective social status. Additionally, the topic of unusual experiences and the recruitment materials likely appealed to specific demographics of people. When considering the suggestion procedure, further limitations might stem from the fact that previous God Helmet experiments were conducted by more senior experimenters, this study was conducted entirely by master students likely portraying less status, confidence, credibility, and expertise. This likely induces less expectations, weakening the placebo effect. At the same time, the sample demonstrated high interest in having an unusual experience, which might strengthen the effect of the placebo manipulation. Ultimately, while inducing on average several unusual experiences per person, the low average M-Score points to an inconsistent success of the placebo-manipulation. This could explain the weak effects found in this study.

In regard to the utilized measures, several strengths and weaknesses need to be considered. This study utilized a grip device as a response method with varied success. Participants had trouble remembering unusual experiences and their order, which made reliable identification and counting of unusual experiences difficult. Data-driven methods to determine grip-events likely included too many grip-events, increasing the signal-to-noise ratio of the data. On the other hand, this response method allowed measuring self-reported experience intensity on a continuous spectrum. While this study's strength lies in assessing physiological responses, it is crucial to acknowledge and discuss limitations of this measure. Due to noisy fEMG several participants were excluded, leading to the final sample size comprising fewer participants than originally planned and reducing the power of analyses, especially those including the corrugator muscle. Additionally, facial emotional responses might not be a reliable indicator of the intensity of experiences with the God Helmet. The sensory deprivation paired with instructions to relax might diminish muscle responses.

In terms of data processing and analysis, several limitations and strengths are notable. While the multiverse analysis covered several possible data processing decisions, it is still possible that emotional responses during unusual experiences were still not captured appropriately. Both baseline methods come with drawbacks: Recording a separate baseline before the session meant that subjects were less relaxed and the instructions of silently counting to 100 might have caused subtle mouth movements, causing noise in the fEMG data. Taking the 45 seconds prior to unusual experiences might also prove fallible, as unusual experiences do not have a fixed length and the baseline windows might therefore include some emotion caused by such experiences. Lastly, the mixed regression models did not fit the data and assumptions were not met, which resulted in deviations from the pre-registered analysis plan (Appendix C).

The observed negative relationship between emotional responses and absorption may guide research on how personality traits, like absorption, influence placebo responses (Kern et al., 2020). By once more validating the role of absorption in placebo responses, this study demonstrates the relevance of taking individual differences into account when administering placebo interventions. Further, results may guide placebo treatment plans to maximize positive outcomes (Enck et al. 2013). However, further investigation is warranted to untangle the effect of absorption on the placebo response and on the regulation of emotions. Specifically, future research might test the influence of absorption on the appraisal process, which mediates emotional responses according to appraisal theories (Moors et al., 2013). The observed negative relationship between emotional responses and absorption also carries implications for future research employing fEMG, emphasizing the relevance of accounting for absorption as a potential contributing factor in emotional expression and regulation.

Insights gained by this study contribute to the challenging and complex endeavor of aligning self-report with objective measures, which has implications for various fields within psychology relying on self-report data (Dang et al., 2020). While studies have identified various objectively measurable placebo effects, other studies have observed a dissociation between self-report and objective measures in placebo manipulations (van Elk et al., 2015; Stewart-Williams & Podd, 2004; Looby & Earleywine, 2011; Schwarz & Büchel, 2015; Vollert et al., 2020). Given the heavy reliance on self-report in disciplines like clinical psychology or psychedelic research, it is important to further develop and test appropriate objective assessment methods that can be administered alongside self-reports to check their validity. The finding of self-rated mysticism predicting increased emotional responses provides physiological evidence for the possibility of evoking mystical experiences within an experimental context, thereby paving the way for future studies further investigating such experiences. However, given that no physiological indicators could be attributed to unusual experiences, future studies should confirm this alignment between physiological responses and self-report by employing more physiological measures such as skin conductance, heart rate variability or respiration.

Furthermore, this research provides insight into the merits and limitations of novel assessment methods and tools, specifically the use of a continuous response device and fEMG. Notably, future studies should consider the difficulty participants encounter when asked to retrospectively remember events. Possible solutions could involve the marking of unusual events with keywords during the session, aiding the memory of participants and facilitating the linkage between physiological measures and self-report.

In conclusion, this study utilized a multiverse approach to examine physiological responses during placebo-induced unusual experiences, analyze their correlation with self-reported occurrences and intensity of the experiences, and investigate the role of individual differences. While evidence for emotional responses during unusual experiences is lacking, findings indicate a positive relationship between emotional responses and self-reported mysticism. However, due to mixed results and small effect sizes, the study does not yield conclusive evidence regarding the authenticity of self-reported unusual or mystical experiences. Further, some evidence supports a negative association between emotional responses and absorption and a positive association between emotional responses and supernatural beliefs. The outcomes of this study contribute to the endeavor of inducing unusual experiences in a controlled environment by comparing self-reports and objective measures. Additionally, they enhance our comprehension of the impact of personality traits and pre-existing beliefs on placebo-induced unusual experiences.

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Appendix A

Non-Standard Questionnaires

Supernatural Belief Questionnaire

Participants will indicate their agreement from 1 (strongly disagree) to 5 (strongly agree) with the following nine statements, which were selected by Lindeman et al. (2019) to represent supernatural beliefs including both religious and other supernatural beliefs:

1. “I believe in God”
2. “I believe in life after death”
3. “The universe originated from intelligent design”
4. “The universe has an ultimate purpose”
5. “I believe in fate”
6. “There is spiritual energy in the universe”
7. “In the universe, everything is connected in a way that cannot be explained scientifically”
8. “Telepathic mind reading is possible”
9. “I believe in angels.”

Altered Self-Consciousness Questionnaire

Participants were asked to indicate their agreement from 1 (strongly disagree) to 5 (strongly agree) to 35 statements relating to the self. This questionnaire was created using a drafted list of items by the first author of Milliere, et al. (2018), items from related measures and self-developed items.

Narrative self

- "My thoughts did not feel like my own"
- "I lost sense of my personal identity"”
- "I could not remember who I was"
-”I was remembering events in my past”
-”What I usually think of myself/How I usually see myself did not matter to me”
- "I felt like I was not in control of my thoughts"
- "I could not think about what was happening to me"

- "I felt as if what was happening was not happening to me"
- “I felt as if my ego dissolved or became less meaningful”
- "I felt a sense of connectedness with the people in my life”
- “I felt a sense of connectedness with the world around me”
- “I had thoughts about myself”
- “I had thoughts about others”
- “My mind was less occupied with everyday thoughts”
- “I felt far less absorbed by my own issues and concerns
- “I lost awareness of my plans for the rest of the day or week”
- “What happened earlier in the day or week did not matter to me”

Multisensory self
- "I could not tell where I was with respect to my physical environment"
- "I could not tell where bodily sensations occurred on my body"
- "I could not tell where was up and down"
- “I was aware of my own bodily signals such as my heartbeat or breathing”
- "My sensations did not feel connected to each other"
- "I could not tell whether I was moving or whether the world was moving"
- "I could not tell the difference between myself and my physical environment "
- "I felt as if I did not have a body anymore"
- “I could not tell where my arms and legs were located relative to the rest of my body”
- "I could not tell whether bodily sensations occurred on the right side or on the left side of my body"
- "I felt as if my body was no longer my own"
- "I felt like I was not in control of my body"
- "I could not feel my body"
- "I felt as if I was no longer located anywhere in space"
- “I felt as if I was no longer located anywhere in time”
- "My perception had no center"
- "My sensations did not feel like my own"

Questions from Griffiths et al. (2006)

We will use three questions from Griffiths et al. (2006) to assess changes in meaningfulness, spiritual significance and subjective well-being after the experience at the lab.

How personally meaningful was the experience?

1= no more than routine, everyday experiences

2= similar to meaningful experiences that occur on average once or more a week

3= similar to meaningful experiences that occur on average once a month

4= similar to meaningful experiences that occur on average once a year

5= similar to meaningful experiences that occur on average once every 5 years

6= among the 10 most meaningful experiences of my life

7= among the 5 most meaningful experiences of my life

8= the single most meaningful experience of my life

Indicate the degree to which the experience was spiritually significant to you

1= not at all

2= slightly

3= moderately

4= very much

5= among the 5 most spiritually significant experiences of my life

6= the single most spiritually significant experience of my life

Do you believe that the experience and your contemplation of that experience have led to change in your current sense of personal well- being or life satisfaction?

+3= increased very much

+2= increased moderately

+1= increased slightly

0= no change

−1= decreased slightly

−2= decreased moderately

−3= decreased very much

Appendix B

Semi-Structured Interviews

It follows the guidelines used for the two semi-structured interview, which were conducted before and after the God Helmet session. Sections to say out loud are highlighted blue. Clarifications and instructions on further question/discussion points are cursive.

Interview before the God Helmet session

So, in this experiment we will use brain stimulation that can lead to extraordinary experiences. To better understand what extraordinary experiences are, we also want to ask you about some mystical experiences you may have had.

So first of all: How would you describe mystical experiences in your own words?”
Follow up with clarification on the characteristics participants report.

How do you think these experiences come to be? Do you think the cause of these experiences can be explained through science?
Follow up to understand whether participants think mystical experiences involve a higher power and whether they think these experiences are fabricated (made up, not real).

[Show explanation video of dimensions of mysticism]

Now please watch this video and let me know when you have finished.

[When the participant has finished, go to the next slide with the summary of mystical experiences. Continue with the interview about previous mystical experiences.]

We will now do an interview for about 20 minutes. As we don’t have much time, please keep this in mind when answering questions.

Now that you know what mystical experiences can be like: How many mystical type experiences have you had in your life?
Ask about experiences that have at least 2 dimensions of the video. Ask participant which of the dimensions the experience had (with help of the image). If no more than 2 dimensions, skip interview. If 2 dimensions but the participant is still doubtful, ask them the interview questions still and ask them to rank. If multiple are mentioned, ask for the participant to describe their two most intense experiences by repeating the following questions.

Let’s start with the most intense one. Take a moment to go back to this experience. When was this experience? Where was it? Can you describe your surroundings/this place? In what context did you have this experience? What might have been the cause of this experience?
Follow up on what psychedelic

Follow up: which moment of that experience was mystical? (if multiple: which of these resembles what was described in the video most). Precise, when did it start, when did it end.

If you think about the part of the experience that you would describe mystical, what was this experience like?

[In the following questions, make sure that the participant is focused on the specific experience. (Was this part of the mystical experience, or something else?)]

Which thoughts came to mind during the experience?

Which feelings came to mind during the experience?

Follow up in terms of emotions

At the point of your mystical experience, did you see/hear/feel anything?

Ask 3 times; Feel: in terms of sensations

When you were having this experience, how did your body/time/space feel?

Ask 3 times; Body: in terms of body as a whole

When you were having this experience, how did you perceive your sense of self?

Follow-up if/how this is different from their normal sense of self.

How did you make sense of this experience while it was happening? How did you interpret or rationalize it afterwards?

How do you think these experiences come to be? Do you think the cause of these experiences can be explained through science?

[Now go back and ask the same questions (4.2.6 - 4.2.13) about the second most intense experience. If multiple mystical experiences are mentioned in 3.1 question, ask the following:]

How did these experiences differ from one another?

What did the experiences have in common?

[End the interview with a short recap of each experience, assigning a keyword to each.
For example: Let's call the experience with ... "X" and the experience where you were .... "Y"]

Interview after the God Helmet session

[For the second interview after the God Helmet session go through each moment they indicated as "unusual" with the button press with the following questions:]

Now let’s go back to what happened at the first [or second, third etc.] button press. What did you experience here? Please start at the beginning, try to put the experiences in order

Which thoughts and feelings came to mind during the experience?

When you were having this experience, did you see/hear/feel anything?

When you were having this experience, how did your body/time/space feel?

When you were having this experience, how did you perceive your sense of self?

Follow-up if/how this is different from their normal sense of self.

Please indicate how you felt during the button press by moving the slider” (fill in the SAM on Qualtrics)

Every little peak should be seen as a button press. If participants don't remember certain button presses, the SAM for that one should be left on neutral. With MS Paint, number the gripper presses that the participant remembered/that are valid presses and not accidental.

[After this, ask the following questions about the experiences taken together:]

How do you make sense of the experiences during the experiment. How do you interpret them?

How did these experiences differ from the experience(s) we talked about before the experiment?

What did the experiences have in common? Do you think they are comparable?

On a scale from 1-5, how much do you think the experiences are comparable?

You can show the top scale on the next page to the participant.

1 = not at all, they were completely different
2 = there may have been some similarities, but I’m not sure
3 = slightly comparable, there were a few similarities
4 = very comparable, the experience reminded me of the other
5 = identical, I felt like I was reliving a previous experience

Think of yourself daydreaming, for example when you get lost in thoughts or you are lost in imagination. Were the experiences with the helmet similar to that?

You can show the top scale on the next page to the participant.

1 = not at all, they were completely different
2 = there may have been some similarities, but I’m not sure
3 = slightly comparable, there were a few similarities

4 = very comparable, the experience reminded me of the other
5 = identical, I felt like I was reliving a previous experience

How strong or intense was the experience with the helmet compared to daydreaming?
You can show the bottom scale on the next page to the participant.

1 = much weaker than daydreaming
2 = a bit weaker than daydreaming
3 = the same as daydreaming
4 = a bit stronger/ more intense than daydreaming
5 = much stronger/more intense than daydreaming

Were there moments where your experience was similar to daydreaming and parts where it wasn't, or was the whole experience the same?"

Here is the list of mystical experiences you filled in at the beginning of this session. Please think of where in this list you would place your experience with the helmet and place it there.

Appendix C

Deviations From Pre-Registration

At the point of initial pre-registration, ordinary linear regressions on one dataset were anticipated. Due to the nested nature of the data and several arbitrary decisions regarding the processing of the data, the analysis plan was changed to include a multiverse analysis that uses mixed models to analyze the relationships between variables. While the mixed models were planned to include random slopes, this addition was dropped due to the model being overfitted – that is, the random effects structure was too complex to be supported by the data in many universes.

I initially planned to associate SAM scores of single grip-events with fEMG scores, however, the pairing of these scores proved difficult due to participants not remembering what had happened for single grip-events and due to an error in the procedure of marking grip-events during the interview. The investigation of a relationship between absorption, M-Scale scores, and fEMG scores was added to the analysis plan. As this data was being collected anyways, the investigation of whether these subjective reports aligned with emotional reactions presented itself. These updates to the analysis plan were uploaded to the OSF website (https://osf.io/sq4zr).

I also anticipated being able to establish that fEMG signals during baseline would be lower than fEMG data during unusual experiences. However, initial descriptive statistics and graphing revealed overall baseline activity to be higher than overall experiment activity, likely due to subjects being more relaxed after prolonged sitting and sensory deprivation. Therefore, a more fair comparison was conceived, where fEMG during unusual experiences are compared with randomly selected periods of the same length during the experiment (these random windows did not overlap with grip-related fEMG windows).

Further, the selection of grip-events using a certain threshold above the mean proved more difficult than anticipated, resulting in a realistic amount of grip-events for many participants. Instead, two additional methods were conceived, using the weakest baseline as a threshold and selecting only the four strongest grips per participant.

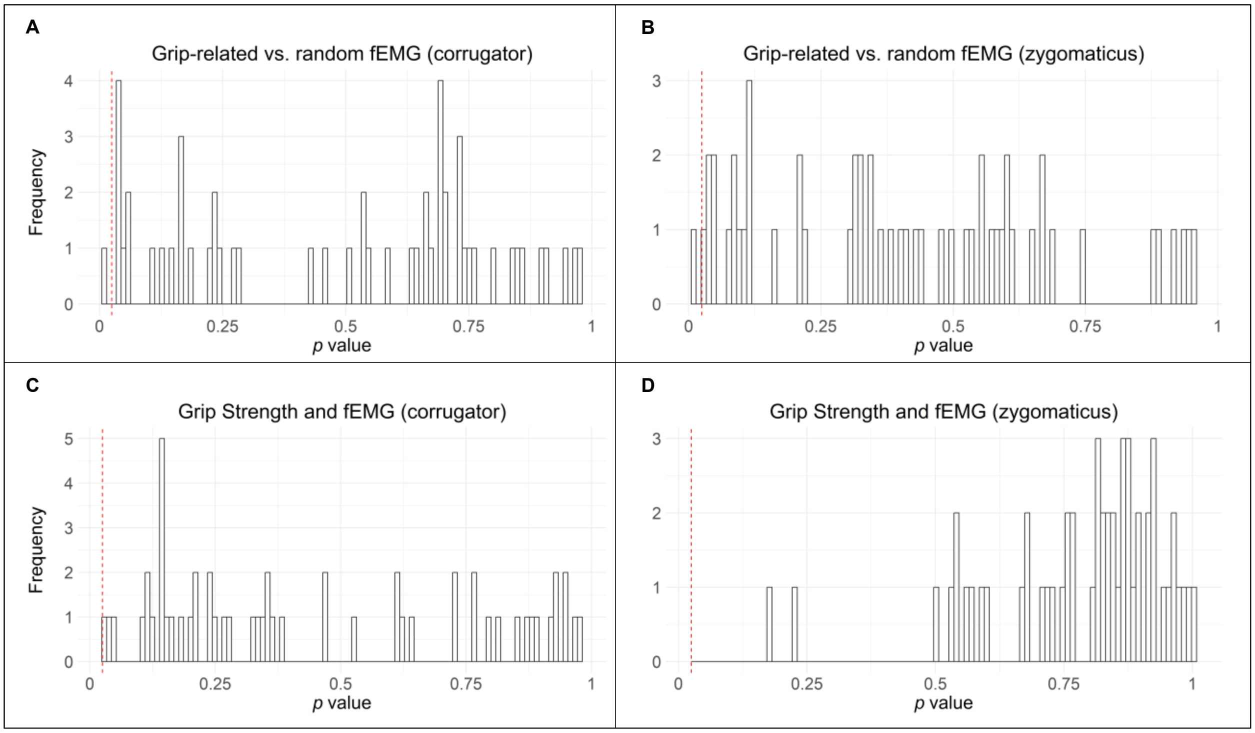
The window surrounding the grip-events over which the fEMG data was averaged was also changed. By graphing the average fEMG activity around grip-events during baseline, it became apparent that the action of gripping had some influence on facial muscle activity, which confounded the analyses. To confirm this an analysis was performed on the baseline data, comparing fEMG data surrounding grip-events with random periods. fEMG data surrounding grip-events were higher, even without any emotional experiences. Therefore, a conservative buffer was included before the grip event based on a visual inspection of the fEMG graphs. Additionally, the 20-second surrounding window parameter was changed to a 5-second preceding window, as the gripper press caused muscle activity to appear to be elevated even after the grip action.

Appendix D

Results From Mixed Regression Analyses

Figure D1

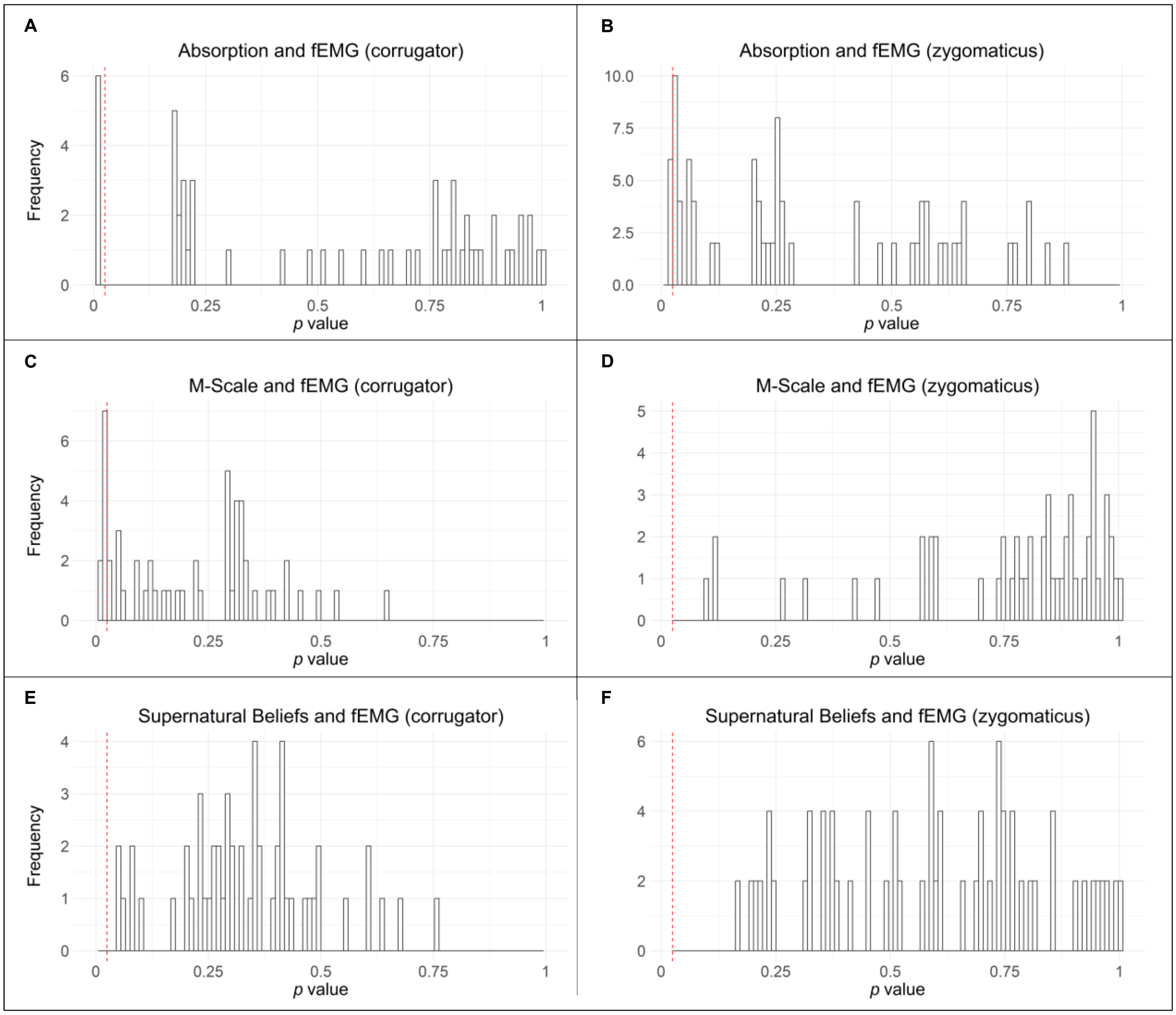
Distributions of p Values From 54 Mixed Model Analyses Conducted for Hypotheses 1 and 2



Note. The red dotted line indicates $p = 0.025$. Total analysis paths = 54. Panels A and B refer the results of the mixed regression model results for the first hypothesis. Panels C and D refer to the second hypothesis. Distributions of p values are generally random with a left skewed distribution in panel D.

Figure D2

Distributions of p Values From 54 Mixed Model Analyses Conducted for Hypotheses 3 and 4



Note. The red dotted line indicates p = 0.025. Total analysis paths = 54. Panels A, B, C and D refer the results of the mixed regression model results for the second hypothesis. Panels E and F refer to the fourth hypothesis. Distributions of p values are generally random with a potential right skew in Panel C and B and a left skew in Panel D.