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An electroencephalographic examination of the autonomous sensory meridian response (ASMR)

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ABSTRACT

Autonomous sensory meridian response (ASMR) is a perceptual phenomenon characterized by pleasurable tingling sensations in the head and neck, as well as pleasurable feelings of relaxation, that reliably arise while attending to a specific triggering stimulus (e.g., whispering or tapping sounds). Currently, little is known about the neural substrates underlying these experiences. In this study, 14 participants who experience ASMR, along with 14 control participants, were presented with four video stimuli and four auditory stimuli. Half of these stimuli were designed to elicit ASMR and half were non-ASMR control stimuli. Brain activity was measured using a 32-channel EEG system. The results indicated that ASMR stimuli—particularly auditory stimuli—elicited increased alpha wave activity in participants with self-reported ASMR, but not in matched control participants. Similar increases were also observed in frequency bands associated with movement (gamma waves and sensorimotor rhythm). These results are consistent with the reported phenomenology of ASMR, which involves both attentional and sensorimotor characteristics.

1. Introduction

Autonomous sensory meridian response (ASMR) is a sensory-emotional phenomenon in which specific auditory, audiovisual, or tactile stimuli, known as “ASMR triggers,” elicit tingling sensations on the scalp, neck, and arms (Barratt & Davis, 2015). The sensorimotor experiences associated with ASMR are often accompanied by a sense of calm that many individuals find helpful in reducing feelings of stress. Previous research has demonstrated that ASMR is commonly elicited by low-frequency, complex sounds and detail-focused, slow-paced visual stimuli (Barratt, Spence, & Davis, 2017). Indeed, multiple survey studies of individuals with ASMR consistently found that whispering, close-up attention, and slow movements such as hair brushing elicited tingles (Barratt & Davis, 2015; Fredborg, Clark, & Smith, 2017, 2018). ASMR has also been linked with repetitive sounds (e.g., finger tapping, gum chewing), suggesting that auditory stimuli can trigger tingles in the absence of visual stimulation (Barratt et al., 2017; Fredborg, Clark, & Smith, 2017). However, surprisingly little is known about the neural structures that cause these auditory and audiovisual stimuli to elicit

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sensory-emotional responses. In the current research, we use electroencephalography (EEG) to measure changes in neural activity when ASMR tingles are elicited by auditory and audiovisual stimuli.

Previous neuroimaging investigations of ASMR have used functional magnetic resonance imaging (fMRI), a technique that provides detailed, three-dimensional depictions of neural activity (e.g., Smith, Fredborg, & Kornelsen, 2017, 2019a, 2019b, 2020). These studies include both resting-state fMRI, which measures correlated fluctuations in neural activity when the participant is not performing a task (Biswal, Yetkin, Haughton, & Hyde, 1995; Raichle et al., 2001; see Raichle, 2015, for a review), and task-based fMRI, which measures neural activity during the performance of a cognitive or motoric task. Resting-state fMRI studies have shown that ASMR is linked with reduced functional connectivity in several of the brain's resting-state networks (Smith et al., 2017, 2019a). These studies also indicate that ASMR is associated with a “blending” of networks in which brain areas not typically associated with a given resting-state network show correlated firing with that network. Task-based studies have shown ASMR-dependent activity in many of these same brain areas. For example, one task-based fMRI study measured the neural responses of 17 individuals with ASMR and 17 control participants during the viewing of ASMR-relevant and non-ASMR videos (Smith et al., 2019b). Participants who reported experiencing ASMR showed increased activity in medial prefrontal regions, bilateral precentral gyri, the right superior prefrontal cortex, the left superior temporal cortex, and midline occipito-parietal structures (precuneus and cuneus) during the viewing of ASMR-relevant videos. Controls participants showed only a decrease in activity in the cuneus. These data demonstrate that the self-reported sensory and emotional changes during ASMR are associated with measurable changes in neural activity. However, although these experiments highlight unique characteristics of ASMR-related brain activity, they do not provide information about the specific changes that occur within an individual during an ASMR tingling experience.

To date, one neuroimaging study has examined the changes in neural activity that occur during ASMR relative to an individual's baseline. An fMRI study by Lochte, Guillory, Richard, and Kelley (2018) measured changes in neural activity occurring over the course of an ASMR video. Ten participants who reported experiencing ASMR viewed five ASMR-eliciting videos (hereafter, “ASMR videos”) and indicated whether they were experiencing baseline responses (i.e., no tingles or changes in emotional state), a feeling of relaxation, or ASMR tingles. When the feeling of relaxation was compared to baseline responses to the video, increased activity was observed in the medial prefrontal cortex. This region was also active during ASMR tingles; however, these sensations—which made up 6% of the scan time in the study—were also associated with activity in a number of other areas, including the bilateral nucleus accumbens, insula, and supplementary motor area, as well in the left secondary somatosensory cortex. Given that these structures are associated with reward responses (e.g., Schultz, 2000), sensitivity to interoceptive feedback (e.g., Craig, 2009), and emotional arousal (e.g., Mazzola et al., 2013; Olivieri et al., 2003), the results are consistent with the reported phenomenology of ASMR (e.g., Barratt & Davis, 2015). However, although informative, the study had some limitations, including the lack of a control group of individuals who are not sensitive to ASMR stimuli.

An additional limitation, relevant to both the Lochte et al. (2018) and Smith et al. (2019b) studies, was that brain activity was measured using fMRI. Although this technique provides excellent spatial resolution, it can only measure activity across the entire brain every 2–3 s. This temporal resolution is not sensitive enough to track fluctuations in neural activity that occur at faster speeds. A second weakness of fMRI is that it is very loud; given that ASMR-relevant stimuli often involve whispering (Barratt et al., 2017), a quieter brain-imaging tool may be more ecologically valid for the study of ASMR. To address these issues, the current study used electroencephalography (EEG) to measure rapid (<1 s) changes in brain activity during the onset of ASMR tingles. This neuroimaging method allows for the presentation of low-volume stimuli such as whispering while brain activity is measured.

EEG is an electrophysiological measurement of neural activity. Sensors placed on the scalp are used to measure changes in the ionic activity of groups of neurons. This ionic activity occurs as a result of ions entering and exiting the ion channels of the neuronal membrane; this activity is associated with action potentials (i.e., a neuron “firing”). When enough similarly charged ions exit a group of neurons at the same time, they form an ion current, a process known as volume conduction. When this current of ions reaches the scalp, it interacts with electrons on the EEG sensors. So, a spike in activity detected by EEG would indicate that the neuronal activity near the EEG sensor has increased (see Jackson & Bolger, 2014; Nunez & Srinivasan, 2006; Olejniczak, 2006).

It is important to note that EEG is a continuous measurement; neurons are constantly firing. However, the rates of firing do change. These changes can occur in response to internal thoughts or external stimuli; they can also occur when an individual enters a different conscious state, as takes place in the different stages of sleep. Previous research has noted that specific frequencies of neural activity are often associated with different phenomenological experiences. Slow delta waves (<4 Hz), for instance, are linked with deep sleep. Alpha waves (8–12 Hz) are often associated with a related state whereas beta waves (16–31 Hz) occur during a more cognitively active state. Gamma waves (>32 Hz) typically reflect somatosensory and sensorimotor responses. Therefore, by examining the prevalence of different EEG waves at specific points in time, it is possible to gain a greater understanding of the types of processes that are occurring at that moment. This is the strategy used in the current examination of ASMR.

Importantly, EEG has been used to measure brain responses in phenomena similar to ASMR. The experience of ASMR has been compared to meditation-like flow states (Barratt & Davis, 2015), although ASMR involves more of a passive response to a stimulus than an active attempt to change conscious states. As a result of this similarity, EEG studies of meditation may provide some insight into the changes in brain activity that occur during the induction of ASMR. Meditation typically involves actively focusing attention on the present moment; many forms of meditation are initiated by focusing on a specific internal or external stimulus such as a body part or a spoken mantra (Lutz, Brefczynski-Lewis, Johnstone, & Davidson, 2008). It also involves focused attention on an external stimulus (e.g., whispering). The link between ASMR and the attentional components of mindfulness was further demonstrated in previous survey studies of 290 individuals with ASMR. ASMR participants demonstrated significantly higher levels of openness-to-experience (according to the Big Five Inventory), as well as higher levels of mindful attention (according to the Mindful Attention and Awareness scale) and a greater tendency to engage in decentering (according to the Toronto Mindfulness Scale) than controls (Fredborg et al.,

2017, 2018). Due to the similarities between experiencing ASMR and focused-attention meditation, as well as the higher levels of several facets of mindfulness reported by ASMR participants, the results of EEG studies of meditative states informed the hypotheses of the current studies. Numerous studies comparing EEG activity in meditative and control (non-meditative) states have reported increases in alpha wave (8–12 Hz) activity (e.g., Aftanas & Golosheikine, 2001; Dunn, Hartigan, & Mikulas, 1999; see Cahn & Polich, 2006 for a review). Literature reviews specific to mindfulness meditation have also noted increases in theta waves (4–7 Hz; see Lomas, Ivtzan, & Fu, 2015, for a review), although the degree to which ASMR is related to this specific form of meditation is uncertain (Roberts, Beath, & Boag, 2019). Given the phenomenological similarities between meditation and ASMR, we would expect that individuals sensitive to ASMR stimuli will show increased alpha power during the perception of these stimuli, particularly at electrode sites near the brain areas identified in earlier fMRI studies, such as the medial prefrontal cortex and precuneus (i.e., Lochte et al., 2018; Smith et al., 2019b). Control participants, on the other hand, would not experience tingling sensations in response to ASMR-related stimuli; therefore, there should be little difference in their responses to ASMR and non-ASMR stimuli.

An additional characteristic of ASMR that can be investigated with EEG is the tingling sensations themselves. These experiences are correlated with physiological arousal (Poerio, Blakey, Hostler, & Veltri, 2018) and may be linked with atypical functional connectivity of the sensorimotor resting-state network (Smith et al., 2019a). Previous research has indicated that gamma waves (30–100 Hz) are associated with verbal sensory and motor processes around the precentral and postcentral gyri (e.g., Cheyne, Bells, Ferrari, Gaetz, & Bostan, 2008; Muthukumaraswamy, 2010). Additionally, neural activity in the 12.5–15 Hz range has been detected over sensorimotor regions during the performance of tasks involving biofeedback; this waveform is known as the sensorimotor rhythm (Arroyo et al., 1993; Cheng et al., 2015; Tansey, 1984). Given that tingling sensations are a key feature of ASMR, it was predicted that ASMR tingles would also be associated with increased gamma wave and sensorimotor rhythm power in these sensorimotor regions.

In the current study, alpha wave, sensorimotor rhythm, and gamma wave activity were examined over the course of the ASMR experience, with an emphasis on the precise moment that ASMR tingles commenced. Over two test sessions, individuals with ASMR and matched control participants viewed two ASMR videos and two non-ASMR videos while EEG measurements were taken. Participants were also presented with four auditory stimuli, two designed to elicit ASMR and two that served as control stimuli. During all eight stimulus presentations (four per test session), participants pressed a response key to indicate the instant that ASMR tingles had begun (if applicable). It was predicted that ASMR participants would show larger changes than control participants in alpha, sensorimotor rhythm, and gamma wave activity in the regions described above during the perception of ASMR-related stimuli. We specifically predicted that increased alpha power would be detected in electrode sites identified to be related to the medial prefrontal cortex and the precuneus, because these regions were associated with ASMR in fMRI studies (e.g., Lochte et al., 2018; Smith et al., 2019b). Increased gamma wave and sensorimotor rhythm would be expected in electrodes near the somatosensory and motor cortices. A second prediction was that ASMR participants would show increases in these three EEG wave bands during the perception of ASMR-related stimuli but not during control stimuli (i.e., non-ASMR stimuli). Finally, we predicted similar patterns of data when comparing neural activity in ASMR participants prior to and during ASMR tingles. This design, combined with the use of EEG, allowed us to measure activity related to the onset of ASMR at a more precise timescale than previous studies. The results of these contrasts will provide data that complement previous fMRI studies of ASMR (Lochte et al., 2018; Smith et al., 2019b) while also generating novel information about neural responses to different types of ASMR triggers.

2. Methods

2.1. Participants

Data from 14 individuals with ASMR (4 males; $M_{age} = 24$; $SD_{age} = 4.85$; age range: 19–37) were analyzed in this study. All ASMR participants had been recruited as part of an earlier investigation of this phenomenon at the University of Winnipeg in Winnipeg, Canada (Smith et al., 2017) and were invited to participate in this study after obtaining their consent to be contacted for additional research opportunities. Fourteen age- and gender-matched control participants (i.e., individuals who do not have ASMR) were also recruited from the Winnipeg, Manitoba community using the same methods (i.e., these participants had also previously been enrolled in an ASMR-related research study). Exclusion criteria for this study included a history of psychiatric or neurological illness. Two additional male participants took part in the study but reported experiencing no ASMR-related tingles to any stimuli during the study. As such, they and their matched control participants were omitted from the analyses (resulting in 14 participants per group as indicated above).

To confirm that participants experienced ASMR (or were control participants who did *not* experience ASMR), all participants watched YouTube.com videos designed to trigger ASMR while being interviewed by one of the authors. Participants were asked to describe their responses to these videos; the wording of the query was kept vague in order to avoid biasing participants' reports. This screening procedure allowed us to classify individuals as being ASMR or control participants. Participants with ASMR also completed the ASMR Checklist (Fredborg et al., 2017) to determine the typical intensity of tingles that they experience to 14 common ASMR-triggering stimuli.

Ethics approval was granted by the University of Winnipeg's Human Research Ethics Board. All participants received \$40 CDN for their time.

3. Stimuli

ASMR audiovisual stimuli. The ASMR-relevant audiovisual stimuli consisted of two popular ASMR videos from YouTube.com.

The first video was entitled “Gently Playing with Hair (soft spoken ASMR)” (<https://www.youtube.com/watch?v=yA2HcNRTdFY>) and featured a female narrator brushing another woman’s hair while narrating her actions to the viewer in a whispering tone. This narration was dubbed over top of the video stimulus, such that the narration was not happening simultaneously, but rather after the fact.

The second video was entitled “Scalp Check (RP) - ASMR — | sleep | relaxation | calm |” (<https://www.youtube.com/watch?v=P1V0e88QyP4>) and featured a black-and-white close-up view of a woman’s face as she pretended to check the viewer’s hair for lice while narrating her actions in a whispering tone of voice.

Control audiovisual stimuli. The control audiovisual stimuli consisted of two videos from YouTube.com. The first video was entitled “How to Grow Shiitake Mushrooms at Home” (<https://www.youtube.com/watch?v=OJHkSL15nMI>) and featured a man explaining to the camera how to grow shiitake mushrooms at home in a loud tone of voice.

The second video was an instructional video on how to create a “Cleopatra-inspired” eye makeup look for Halloween. It featured a male make-up artist (Jordan Liberty) applying makeup to a woman’s face while narrating his actions in a loud tone of voice. The video is no longer available on YouTube.com.

ASMR audio-only stimuli. The ASMR audio-only stimuli consisted of the audio from a popular ASMR YouTube video entitled “An Esthetician Visit - Binaural Role Play - ASMR - Face Massage, Water Sounds, Soft Speaking” (https://www.youtube.com/watch?v=LMS-VIbc_48). The audio from this video features a woman whispering to the viewer (the “client” in this roleplay) instructions for their “first ever esthetician visit.” The audio was split into two four-minute-long sections to comprise each stimulus.

Control audio-only stimuli. The control audio-only stimuli consisted of a verbatim audio recording of the transcript from the ASMR audio-only stimuli. Although the content was the same, it was re-recorded by one of the female authors (BKF) in a loud and abrupt tone of voice designed to *not* elicit ASMR experiences (see Barratt et al., 2017, for a description of the auditory characteristics associated with ASMR-inducing stimuli).

4. Measures

The ASMR Checklist. Participants in the ASMR condition completed the ASMR Checklist (Fredborg et al., 2017), which is a measure of both average tingle intensity experienced as well as the average duration the stimuli needs to be before tingles are experienced in response to 14 popular ASMR triggers. All ASMR participants reported that they experienced ASMR reliably. Due to the small sample size and relative homogeneity of the responses, the data from the ASMR Checklist did not contribute meaningful data to this study (although please see Smith et al., 2020, for a discussion of how the ASMR Checklist data *are* related to individual differences in the functional connectivity of fMRI resting-state networks). Therefore, it will not be discussed further.

4.1. Procedure

All participants underwent two experimental sessions involving EEG measurements of brain activity. In the first session, an EEG measurement of each participant’s resting-state brain activity was conducted. Resting-state measurements consisted of a 7-minute trial in which participants were asked to sit still with their eyes closed (i.e., no stimuli were presented). Resting state data were not analyzed further in the current study; those analyses will be used in a comparison of EEG and fMRI resting-state activity in ASMR (see Smith et al., 2019a).

Next, ASMR responses to two audiovisual and two solely auditory stimuli were assessed over four separate experimental trials. One ASMR audio stimulus and one ASMR-video stimulus were presented in each session; each session also included one non-ASMR (control) audio and video stimulus, for a total of four stimuli. All stimuli were presented using E-Prime 2.0 software (Psychology Software Tools, Inc., Pittsburgh, PA).

Each trial consisted of the presentation of (1) a one-minute blank black screen with a white center fixation cross, (2) a four-minute audiovisual or audio-only (over a blank black screen) stimulus, and a (3) two-minute blank black screen with a white center fixation cross following the offset of the stimulus. During these trials, individuals indicated whether they experienced ASMR by pressing a button on a response device to indicate the point during the stimulus presentation at which they began to experience tingles (ASMR onset). Following each trial, if a participant indicated experiencing tingles, they were then asked to rate the intensity of the tingling sensation on a Likert-type scale from 1 to 10, with “1” referring to the weakest tingling sensation ever experienced and “10” referring to the strongest tingling sensation ever experienced.

In the second test session, participants once again entered the laboratory and completed the same experimental procedure; however, they were presented with the two audiovisual and two audio-only stimuli that they had not experienced in the first experimental session and did not complete the 7-minute resting state. These stimuli were counterbalanced across participants to reduce order effects.

5. Data acquisition and preprocessing

Data were acquired using a 32-channel Actichamp II system, with Ag/AgCl electrodes positioned in the standard international 10–20 arrangement using ActiCaps (BrainVision, LLC, Morrisville, NC). Data were recorded at a sampling rate of 500 Hz and digitally referenced online to Fz using BrainVision PyCorder. Impedances were kept below 20 kΩ. Horizontal electrooculogram electrodes were placed at the temples, and vertical electrooculogram electrodes were placed above the middle of the eyebrow and below the middle of the left eye, to monitor for horizontal eye movements and blinks, respectively.

Data were preprocessed in MATLAB (v. R2018a, The MathWorks, Inc., Beltsville, MD) using the EEGLAB toolbox (v. 14.1.2; Delorme & Makeig, 2004). Raw data were first down-sampled to 250 Hz and trimmed to include only the periods during which stimuli were presented. Line noise was then removed, channels re-referenced to the average of all scalp sites, and bad channels interpolated using the PREP automated preprocessing pipeline EEGLAB plugin (v. 0.55.3; Bigdely-Shamlo, Mullen, Kothe, Su, & Robbins, 2015). Data were then high-pass filtered at 0.5 Hz and low-pass filtered at 40 Hz to minimize artifacts from muscle contractions and line noise (see Cohen, 2014). Eye-blink and muscle artifacts were removed by independent component analysis guided by the EEGLAB plugins SASICA (v. 1.3.4; Chaumon, Bishop, & Busch, 2015) and ADJUST (v. 1.1.1; Mognon, Jovicich, Bruzzone, & Buiatti, 2011). Data were then trimmed into 12-second epochs containing only the period ± 6 s surrounding the ASMR onset time (i.e., the point at which the participant pressed the response button). In the case of control participants and non-ASMR-inducing control stimuli, the ASMR onset time recorded from the matched ASMR participant was used. More specifically, the ASMR onset time for a control participant during an ASMR stimulus was the ASMR onset time indicated by the age- and sex-matched ASMR participant during that same stimulus. Moreover, that same ASMR onset time was used for the corresponding control stimulus for both ASMR and control participants. As such, each pair of age- and sex-matched ASMR and control participants was matched on the specific time point within the recording from which their EEG data was sampled.

6. EEG Time-Frequency analysis

Pre-processed epochs were then decomposed to time–frequency domain by complex Morlet wavelet convolution (Cohen, 2014). A total of 30 wavelets were used, ranging logarithmically from 2 Hz to 40 Hz. The number of wavelet cycles also ranged logarithmically from 3 cycles (at 2 Hz) to 10 cycles (at 40 Hz). The resulting time–frequency power data were decibel-normalized to the average baseline power of the period from 1000 ms to 500 ms prior to ASMR onset. Decibel-normalized data were then exported to R (v. 3.4.4; R Core Team, 2018) for further analysis.

7. Data analysis

As described above, participants with ASMR were instructed to press a button on a response pad when they initially felt tingling sensations for a given stimulus trial. To minimize movement-related artifacts, we computed the average power for each frequency for the period from 500 ms to 1000 ms following ASMR onset. These values were then used for subsequent analyses described below.

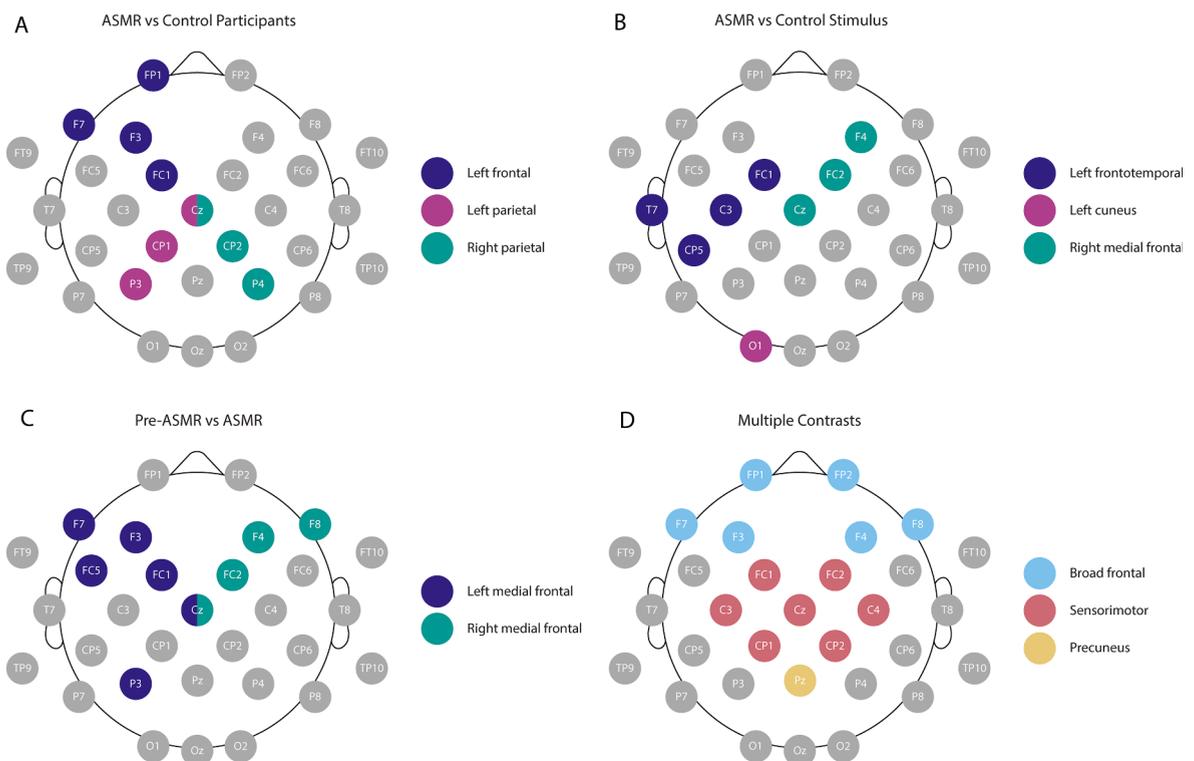


Fig. 1. Electrode groups used for *a priori* contrasts. Electrode groups were chosen based on previous research as described in the Methods. Individual electrodes were averaged for pairwise comparisons between A) ASMR and control participants; B) ASMR and control stimuli; C) baseline (pre-ASMR) vs after ASMR onset; or D) all three contrast types. Electrodes with multiple colors represent an electrode that was used in the two indicated groups.

Where appropriate, these were compared against the average of the baseline period (1000 ms to 500 ms prior to ASMR onset). The average power for each trial per electrode channel was then calculated to compute average alpha (8–12 Hz), sensorimotor response (12.5–15 Hz), theta (4–7 Hz), and gamma (>30 Hz) power. Many ASMR participants reported experiencing significant ASMR-related tingles during only one of each audio or audiovisual stimulus; for this reason, we selected only the higher-rated audio and audiovisual trials for further analysis. Two participants did not experience ASMR for either audio track, and two participants did not experience ASMR for either video file. Data from these participants were used in conditions where they did report experiencing ASMR and excluded in conditions where they did not. These participants are in addition to the two participants described in the *Participants* section who reported experiencing no ASMR to any of the stimuli in the study.

As described above, we had clear hypotheses regarding regions of interest for alpha, sensorimotor rhythm, and gamma frequency bands. To assess these *a priori* contrasts, the average power of relevant electrode groups was compared across groups by a directional Welch's unequal variance *t*-test (*t*) and the magnitude of the difference was calculated as Hedge's *g* (*g*). Within-subject comparisons were performed using directional paired *t*-tests (*t*). Electrode groupings for *a priori* contrasts were determined by averaging the electrodes into groups that broadly map onto regions that were active in previous neuroimaging studies of ASMR (Lochte et al., 2018; Smith et al., 2019b). These included (1) regions that were active during ASMR stimuli in ASMR participants but not control participants (i.e., between-group contrasts; see Smith et al., 2019b), (2) during ASMR but not control stimuli in ASMR participants (i.e., within-subjects stimulus contrasts for ASMR participants; see Smith et al., 2019b), or in ASMR participants after ASMR onset but not before it (i.e., within-subjects time contrasts; see Lochte et al., 2018). These ERP sensor groupings are displayed in Fig. 1.

In addition to the hypothesized effects above, we sought to determine whether ASMR altered activity elsewhere in the brain in the alpha, theta, or gamma bands. To conduct these exploratory analyses, we analyzed the data using a $2 \times 2 \times 2 \times 31$ mixed-factorial analysis of variance (ANOVA), with subject group (ASMR vs control participants) as the between-subjects factor and condition (ASMR vs control stimuli), time (baseline vs post-tingle period), and electrode channel as within-subjects factors. Separate ANOVAs were conducted for stimulus type (audio vs video) and frequency band (alpha, sensorimotor rhythm, theta, and gamma). Notable main effects and interactions are reported (*F*), with the magnitude of the effect reported as generalized eta-squared (η^2_G). Post-hoc pairwise comparisons were then computed. For between-group comparisons, we used a non-directional Welch's unequal variance *t*-test (*t*) and report the magnitude of the difference as *g*. For within-subject comparisons, the paired versions of these same tests were used. To control the false-discovery rate, raw *p*-values from post-hoc tests were adjusted according to the Benjamini-Hochberg method (Benjamini & Hochberg, 1995) and are reported if the adjusted value passes a cutoff of $p = 0.05$.

Data were analyzed in R (v. 3.4.4; R Core Team, 2018) using the *ez* (Lawrence, 2016) and *effsize* (Torchiano, 2017) packages. Post-hoc *p*-values were adjusted by the Benjamini-Hochberg method using the *p.adjust* function in R. Topographical scalp effect size heatmaps were created in R by adapting MATLAB's v4 method from the *griddata* function (as per Craddock, 2017) to interpolate values of Hedge's *g* and were drawn using the *ggplot2* package (Wickham, 2016). Graphs were created in GraphPad Prism (v. 6.01, GraphPad Software, San Diego, CA, USA). Figures were assembled with Adobe Illustrator (v. 19.0, Adobe, Inc., San Jose, CA, USA).

8. Results

We will first describe the results of our *a priori* hypotheses which focus on specific groups of EEG electrodes. We will then describe the results of the ANOVAs that include all of the EEG electrodes; these analyses are exploratory in nature. Additionally, given the relatively small sample size in this study, some contrasts were not statistically significant but did yield a moderate (i.e., noteworthy) effect size. The descriptions of the results will therefore include both information about statistical significance (i.e., *p*-values) as well as

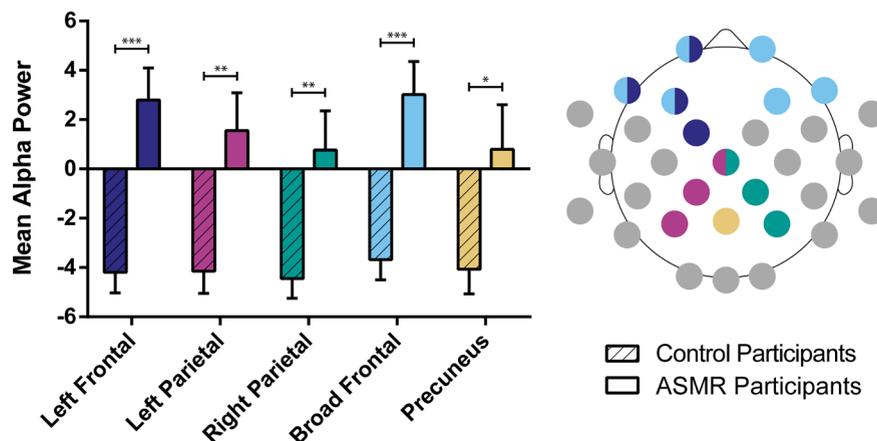


Fig. 2. Difference in mean alpha power between ASMR and control participants during ASMR audio. Pairwise comparisons were made between control (diagonal lines) and ASMR (no pattern) participants for each *a priori* electrode group. The location of electrodes that comprise each group are indicated in the schematic scalp map by corresponding color. Error bars represent 1 standard error of the mean. *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

effect sizes. Additionally, we will include results that were “marginally significant” (i.e., $p = 0.05\text{--}0.10$), as these results may help inform the hypotheses of future ASMR studies.

8.1. *A priori contrasts related to alpha power*

8.1.1. *Between-Group contrasts during ASMR Tingles*

We first examined whether ASMR increased alpha power in ASMR participants relative to matched controls in regions of interest (i.e., between-group contrasts). This was the case during ASMR audio trials (see Fig. 2); we found significantly increased alpha power in left frontal electrodes (Fp1, F7, F3, and FC1; $t_{18,8} = 4.55$, $p = 0.00011$, $g = 1.79$), left parietal electrodes (CP1, P3, and Cz; $t_{17,8} = 3.21$, $p = 0.0024$, $g = 1.27$), right parietal electrodes (P4, CP2, and Cz; $t_{16,3} = 2.92$, $p = 0.0049$, $g = 1.15$), a broad group of frontal electrodes (F3, F7, Fp1, F4, F8, and Fp2; $t_{18,2} = 4.26$, $p = 0.00023$, $g = 1.68$), and near the precuneus (Pz; $t_{17,2} = 2.34$, $p = 0.016$, $g = 0.92$). When looking instead at ASMR video trials, we found a significant increase near the precuneus ($t_{19,8} = 1.79$, $p = 0.044$, $g = 0.71$), but no notable differences in any other regions.

8.1.2. *Within-Subjects stimulus contrasts during ASMR Tingles*

We then examined whether increased alpha power could be detected in participants during ASMR-inducing stimuli relative to control stimuli (i.e., within-subjects stimulus contrasts). These data are depicted in Fig. 3. When comparing ASMR audio trials to control (non-ASMR) audio trials, we found that ASMR participants experienced a significant increase in alpha power near the left cuneus (O1; $t_{11} = 2.23$, $p = 0.024$, $g = 0.85$) and in a broad group of frontal electrodes (F3, F7, Fp1, F4, F8, and Fp2; $t_{11} = 2.18$, $p = 0.026$, $g = 1.03$). We also found a marginally significant increase in right medial frontal electrodes (F4, FC2, and Cz; $t_{11} = 1.76$, $p = 0.053$, $g = 0.79$) and in left frontotemporal regions (FC1, C3, CP5, and T7; $t_{11} = 1.40$, $p = 0.095$, $g = 0.64$). By contrast, the same comparison in control participants showed no significant differences in alpha power in any region (data not shown). We also compared alpha wave activity in the left and right frontal regions in order to determine any hemispheric differences were present during the ASMR experience; however, no significant effects were found.

Analyses examining differences in alpha power levels between ASMR video trials and control video trials produced only a marginally significant effect in the precuneus region (Pz; $t_{11} = 1.37$, $p = 0.099$, $g = 0.46$) in ASMR participants.

8.1.3. *Within-Subjects contrast of baseline activity and ASMR Tingles*

Finally, we examined whether increased alpha power could be detected in participants during the experience of ASMR relative to the baseline period prior to the onset of self-reported ASMR tingles (see Fig. 4). This contrast specifically examined changes in neural activity when the conscious experience of individuals with ASMR changed and tingling sensations began (i.e., within-subjects time contrasts). For ASMR participants during ASMR audio trials, we found significant increases in broad frontal regions (F3, F7, Fp1, F4, F8, and Fp2; $t_{11} = 3.42$, $p = 0.0029$, $g = 1.48$), and for two groups of electrodes that overlapped with areas of activity detected in an earlier fMRI study by Lochte and colleagues (2018): right medial frontal regions (Cz, FC2, F4, and F8; $t_{11} = 2.74$, $p = 0.0097$, $g = 1.15$), and left medial frontal regions (Cz, FC1, F7, F3, P3, and FC5; $t_{11} = 3.02$, $p = 0.0058$, $g = 1.25$).

By contrast, during ASMR audio trials in control participants, when comparing baseline to the time period that matched ASMR participants reported experiencing ASMR, we found strong *decreases* in alpha power in broad frontal ($t_{11} = -2.39$, $p = 0.036$, $g = -0.91$), right medial frontal ($t_{11} = -2.97$, $p = 0.013$, $g = -1.29$), left medial frontal, and precuneus ($t_{11} = -2.22$, $p = 0.048$, $g = -0.87$) regions.

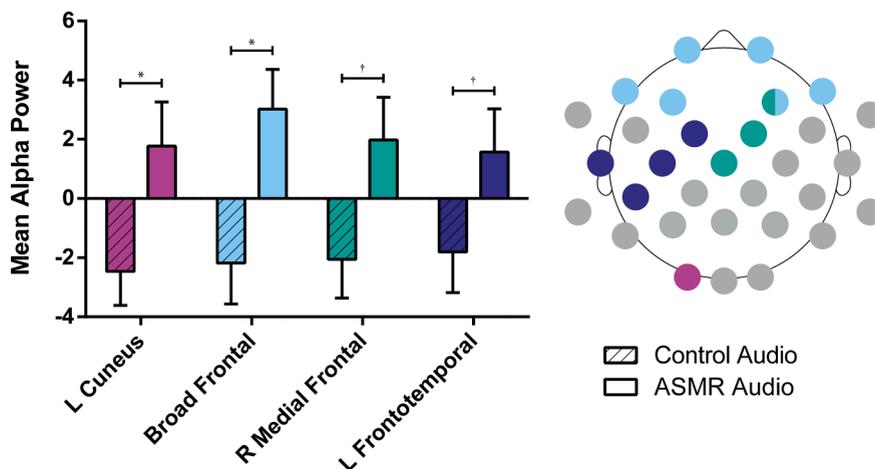


Fig. 3. Difference in mean alpha power in ASMR participants between ASMR and control audio. Pairwise comparisons were made between control (diagonal lines) and ASMR (no pattern) audio for each *a priori* electrode group. The location of electrodes that comprise each group are indicated in the schematic scalp map by corresponding color. Error bars represent 1 standard error of the mean. * $p < 0.05$; † $p < 0.1$.

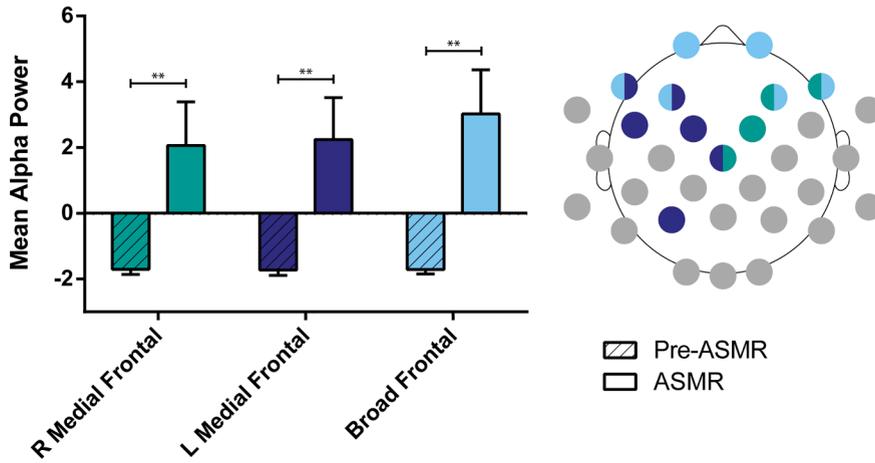


Fig. 4. Difference in mean alpha power in ASMR participants between baseline and after ASMR onset. Pairwise comparisons were made between baseline (pre-ASMR; diagonal lines) and after participants indicated ASMR onset (no pattern) for each *a priori* electrode group. The location of electrodes that comprise each group are indicated in the schematic scalp map by corresponding color. Error bars represent 1 standard error of the mean. ** $p < 0.01$.

For ASMR participants during ASMR video trials, contrasting average alpha power post ASMR onset to baseline revealed a near-significant increase near the precuneus with a moderate-to-large effect size ($t_{11} = 1.68, p = 0.061, g = 0.68$). The same comparisons in control participants revealed no significant differences in any regions (data not shown).

9. A priori contrasts related to gamma power

9.1. Between- and Within-Subjects contrasts during ASMR Tingles.

There were no significant increases found in gamma power in sensorimotor electrodes (FC1, FC2, C3, Cz, C4, CP1, and CP2) between participant groups for either ASMR audio or ASMR video trials ($ps > 0.05, gs \leq 0.39$). When comparing ASMR audio trials to control audio trials for ASMR participants, however, we did identify a large and significant increase in gamma power ($t_{11} = 2.39, p = 0.018, g = 0.76$; see Fig. 5) that was not seen in the same comparison for control participants ($t_{11} = 0.01, p = 0.99, g = 0.003$). No significant changes were seen when comparing ASMR video trials to control video trials for either ASMR or control participants ($p > 0.50$ for both comparisons).

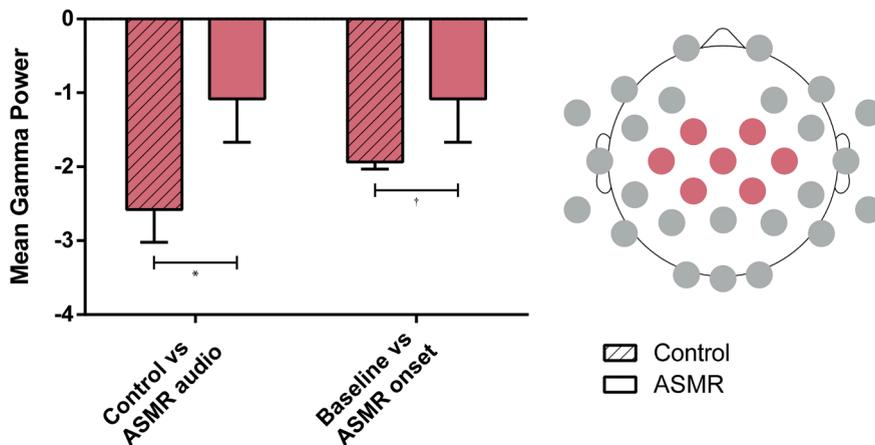


Fig. 5. Differences in mean gamma power in ASMR participants during audio stimuli. Pairwise comparisons of grouped sensorimotor electrodes from ASMR participants were made between control (diagonal lines) and ASMR (no pattern) audio or during ASMR audio between baseline (diagonal lines) and ASMR onset (no pattern). The location of electrodes that are included in the analysis are indicated by color in the schematic scalp map. Error bars represent 1 standard error of the mean. * $p < 0.05$; † $p < 0.1$.

9.2. Within-Subjects contrast of baseline activity and ASMR Tingles.

We found similar results when contrasting average gamma power post-ASMR onset to baseline (i.e., when examining neural changes during the onset of ASMR tingles). ASMR participants showed a nonsignificant increase in gamma power during ASMR audio trials ($t_{11} = 1.44, p = 0.089, g = 0.54$) but not during ASMR video trials ($t_{11} = -0.59, p = 0.72, g = -0.24$). We found no significant change in gamma power for control participants during either ASMR audio or video trials (data not shown).

10. A priori contrasts associated with sensorimotor rhythm

10.1. Between- and Within-Subjects contrasts during ASMR Tingles.

When examining sensorimotor rhythm over sensorimotor regions (C3, Cz, C4), we found a significant increase in power in ASMR participants relative to control participants after ASMR onset during ASMR audio trials ($t_{11} = 2.90, p = 0.0047, g = 1.14$; see Fig. 6) and a nonsignificant increase during ASMR video trials ($t_{11} = 1.31, p = 0.10, g = 0.52$). A similar, though nonsignificant, increase was found for ASMR participants during ASMR audio trials relative to control audio trials ($t_{11} = 1.51, p = 0.079, g = 0.69$). No such differences were seen for control participants (data not shown).

10.2. Within-Subjects contrast of baseline activity and ASMR tingles

Finally, we examined whether ASMR onset timing influenced sensorimotor rhythm power. For ASMR participants we found a large and significant increase in power after ASMR onset relative to baseline during ASMR audio trials ($t_{11} = 1.98, p = 0.037, g = 0.85$); this contrast was not significant for ASMR video trials ($p = 0.20$). Surprisingly, this same contrast in control participants revealed a significant decrease in sensorimotor rhythm power during ASMR audio trials ($t_{11} = -2.46, p = 0.032, g = -0.90$); there was no significant difference during ASMR video trials ($p > 0.30$).

11. Exploratory analyses

As noted earlier, exploratory analyses were performed to detect any significant effects that would not have been predicted from earlier fMRI studies of ASMR (Lochte et al., 2018; Smith et al., 2019b). For these exploratory analyses, we used ANOVAs to determine whether any noteworthy effects existed for either audio or video trials on alpha, theta, or gamma frequency bands.

For alpha power during audio trials we found a significant main effect of group (i.e., ASMR or control participants; $F_{1,22} = 6.18, p = 0.021, \eta^2_G = 0.028$) and moderate interactions of group \times condition ($F_{1,22} = 3.35, p = 0.081, \eta^2_G = 0.033$), group \times time ($F_{1,22} = 8.68, p = 0.0075, \eta^2_G = 0.034$), group \times condition \times time ($F_{1,22} = 3.79, p = 0.065, \eta^2_G = 0.040$), and condition \times channel \times time ($F_{30,660} = 1.35, p = 0.10, \eta^2_G = 0.0053$). In contrast, the analyses of alpha power during video trials yielded only marginally significant main effects of time (i.e., baseline vs ASMR onset; $F_{1,22} = 3.32, p = 0.082, \eta^2_G = 0.011$) and condition (i.e., ASMR or control trial; $F_{1,22} = 3.09, p = 0.092, \eta^2_G = 0.0092$).

Given the noteworthy group \times condition \times time and condition \times channel \times time interaction effects, we examined whether any

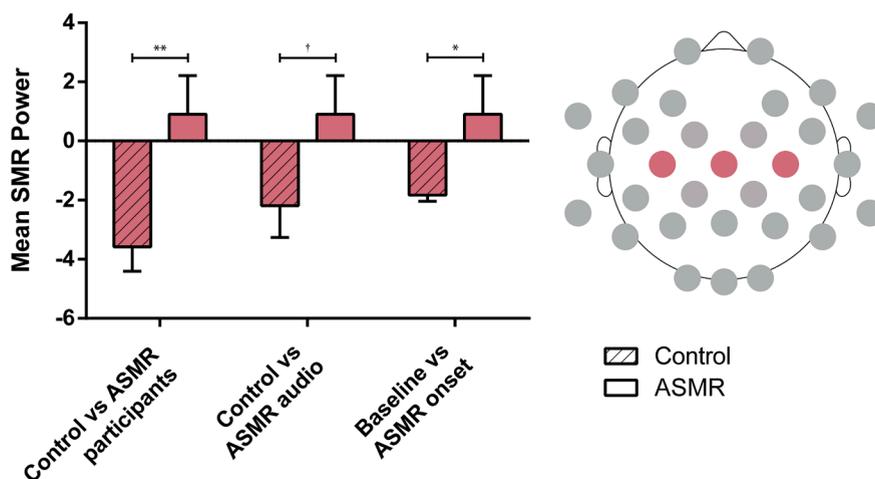


Fig. 6. Differences in mean sensorimotor rhythm power in ASMR participants during audio stimuli. Pairwise comparisons of grouped sensorimotor electrodes were made between control (diagonal lines) and ASMR (no pattern) participants during ASMR audio (left), between control (diagonal lines) and ASMR (no pattern) audio in only ASMR participants (center), or during ASMR audio between baseline (diagonal lines) and ASMR onset (no pattern) in only ASMR participants (right). The location of electrodes that are included in the analysis are indicated by color in the schematic scalp map. Error bars represent 1 standard error of the mean. ** $p < 0.01$; * $p < 0.05$; † $p < 0.1$.

significant differences on alpha power existed between ASMR and control participants during ASMR audio following ASMR onset. *Post-hoc* analyses demonstrated widespread increases in alpha power throughout frontal electrodes ($p < 0.05$ for each of FP1, FP2, F3, F4, F7, F8, FC1, FC5, FC6, Cz, and C3), with similar increases in other regions ($p < 0.05$ for O2, Oz, CP6, P3, P4, P8, T7, and TP10; see Fig. 7). To confirm the relevance of these areas, we conducted additional post-hoc tests between ASMR and control audio post ASMR onset for ASMR participants only; these analyses yielded significant effects at electrode sites P3 and P4 ($p < 0.05$). We also compared baseline activity to post-ASMR onset for ASMR participants during ASMR audio trials. Significant differences were observed at electrode sites F3, F4, FP1, FC5, FC6, and C3 ($p < 0.05$).

We found no noteworthy effects on theta power during video trials. In contrast, during audio trials, we found a marginally significant main effect on theta power of time ($F_{1,22} = 3.39, p = 0.079, \eta^2_G = 0.013$) and as well as a marginally significant interaction effect of group \times condition ($F_{1,22} = 3.34, p = 0.081, \eta^2_G = 0.019$). Given these effects, we examined whether any significant differences existed between ASMR and control participants during ASMR audio trials following the onset of ASMR tingles. Though we did see moderate increases in theta power in several regions, none were significant after false-discovery-rate correction.

Exploratory analyses also examined gamma power. We found a significant main effect of channel ($F_{30,660} = 1.96, p = 0.0018, \eta^2_G = 0.013$) and a significant interaction effect of channel \times time ($F_{30,660} = 2.16, p = 0.00039, \eta^2_G = 0.014$) during video trials, and a condition \times channel interaction ($F_{30,660} = 1.67, p = 0.015, \eta^2_G = 0.011$) on gamma power during audio trials. Given the lack of significant effects involving group, these effects did not justify any meaningful post-hoc tests.

12. Discussion

The purpose of the current research was to examine changes in neural activity associated with the onset of ASMR. The use of EEG allowed us to examine these changes in conscious state at a much more precise temporal resolution than was possible in fMRI experiments. In the current study, we tested individuals with self-reported ASMR and matched control participants in order to address three specific questions. First, how does brain activity during ASMR “tingles” differ from time-locked brain activity in control participants? Second, how do neural responses of individuals with ASMR differ during the perception of ASMR-inducing stimuli and non-ASMR stimuli? Third, what changes in brain activity occur when an ASMR experience begins (i.e., when an individual’s conscious state changes from “baseline” to ASMR tingles)? Our experimental design also incorporated an additional variable: the modality of the stimuli. We were therefore able to examine whether the answers to these three questions differed for audio and audiovisual stimuli. In this Discussion, we will discuss the results of these four research questions. As part of this discussion, we will highlight how changes in the activity of different frequency bands—alpha waves (8–12 Hz), sensorimotor rhythm (12.5–15 Hz), and gamma waves (<30 Hz)—were consistent with the reported phenomenology of the ASMR experience.

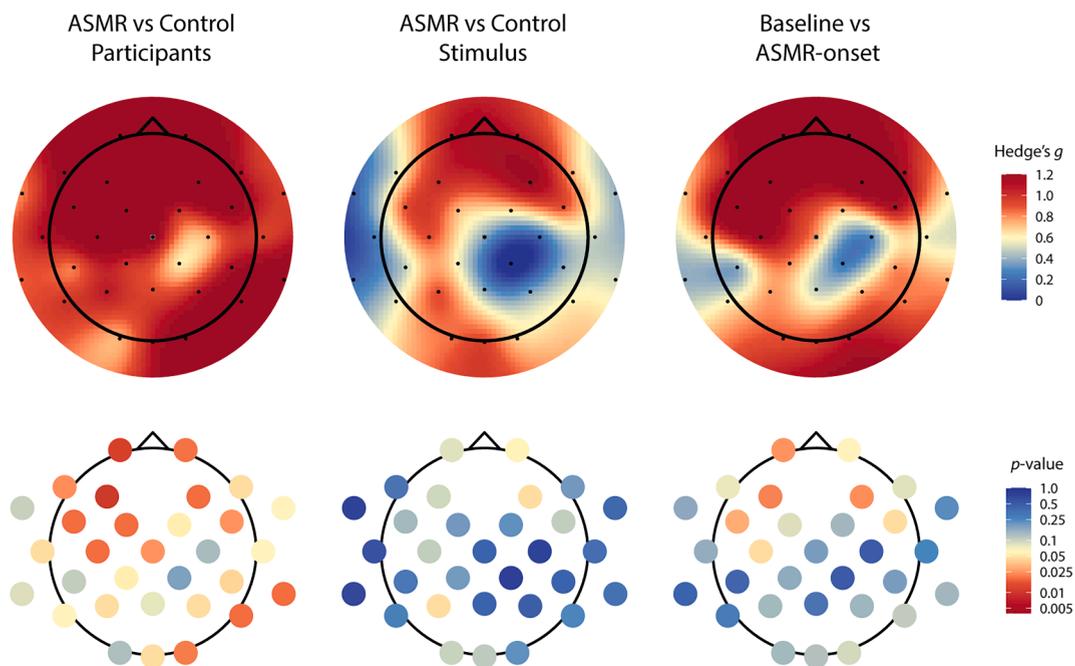


Fig. 7. Exploratory analyses of alpha power in ASMR participants during audio stimuli. Post-hoc comparisons were calculated to compare individual electrodes between ASMR and control participants during ASMR audio (left column); between ASMR and control audio in ASMR participants (middle column); and between baseline and after ASMR onset in ASMR participants during ASMR audio. Effect size was calculated as Hedge’s g and interpolated between electrodes (top row), while p -values were corrected for false discovery rate and are presented as exact values for each electrode tested.

Multiple studies have reported that ASMR consists of a relaxed, flow-like conscious state (e.g., Barratt & Davis, 2015; Fredborg et al., 2017). Similar phenomenology is reported in some forms of meditation (Lutz et al., 2008), although it must be stressed that meditation is a more active and effortful process than ASMR. The process of entering and maintaining a meditative state is frequently linked to changes in alpha wave activity (e.g., Aftanas & Golocheikine, 2001; Dunn et al., 1999). We therefore hypothesized that ASMR would lead to increased alpha activity, particularly in the prefrontal cortex and precuneus, which are regions that showed ASMR-dependent activity in fMRI investigations (Lochte et al., 2018; Smith et al., 2019b). The results were largely consistent with our predictions. The ASMR experience was associated with increased alpha activity in frontal and parietal sites in the between-group contrast and in the within-subjects contrast when ASMR-sensitive individuals heard ASMR-related vs. ASMR-unrelated audio files. Increased frontal activity was also detected when we compared the brain activity during ASMR tingles to pre-tingle activity during audio trials. These differences may indicate that the conscious experience of ASMR is similar to the flow-like state associated with some forms of meditation. However, given that much of the alpha activity was detected in frontal regions, it may also indicate changes in experiential absorption, response inhibition, or attentional control, all of which are influenced by the ASMR experience (Janik McErlean & Osborne-Ford, 2020; Wang, Yang, Sun, & Su, 2020). Future studies should expand on this initial finding by examining whether fluctuations in this alpha activity is related to moment-to-moment changes in ASMR intensity.

One surprising result involved alpha wave activity in control participants. These individuals showed *decreases* in alpha power when comparing pre- to post-tingle onset for their ASMR participant counterparts during ASMR audio trials. One possible explanation is that ASMR stimuli are often perceived as strange—sometimes even discomfiting—by individuals who do not experience the phenomenon. In this case, the decreases in alpha waves may reflect an increase in tension or an active attempt to disengage attention from the stimuli. However, as we did not record physiological responses (e.g., galvanic skin response) during this study, we can only speculate as to the cause of this unexpected result.

Individuals with ASMR also consistently report experiencing tingling sensations on the scalp, neck, and shoulders (Barratt & Davis, 2015). In order to elucidate the neural activity associated with this aspect of ASMR phenomenology, we examined two different frequencies of brain activity, the sensorimotor rhythm (12.5–15 Hz) and gamma waves (>30 Hz). We hypothesized that changes in these frequency bands would occur over the primary and secondary motor and somatosensory cortices. The changes in gamma wave and sensorimotor rhythm activity were not as pronounced as the alpha-wave activity discussed above. However, consistent with our hypotheses, increased activity did occur in both frequency bands for audio trials when comparing ASMR to control participants and when comparing pre-tingle to post-tingle activity in ASMR participants. Analyses of sensorimotor rhythm activity also revealed higher levels of activity during ASMR participants' responses to ASMR-relevant audio files as compared to ASMR-irrelevant audio files. These changes in sensorimotor rhythm and gamma wave activity suggest that individuals with ASMR perceived a sensorimotor experience during ASMR.

One potential explanation for these results is that ASMR participants pressed a button to indicate the onset of tingles, whereas this did not occur for non-ASMR videos or for control participants. Although this difference between experimental conditions—discussed in detail in the Limitations sections below—may underlie *some* of the sensorimotor rhythm and gamma wave results, there is still reason to believe that the ASMR experience itself plays a role in these effects. This is because fewer significant effects were found for video trials. If the button press itself were the sole contributor to the observed sensorimotor rhythm and gamma wave effects, then the video conditions should also have produced significant results.

Additional analyses were performed to determine whether ASMR was associated with changes in theta wave (4–7 Hz) activity. This decision was based on the fact that many previous studies of mindfulness meditation showed changes in this frequency band (Lomas et al., 2015). Given that ASMR is associated with higher scores on the Mindful Attention and Awareness Scale (Brown & Ryan, 2003) and on the curiosity subscale of the Toronto Mindfulness Scale (Lau et al., 2006; see Fredborg, Clark, & Smith, 2018), it seemed reasonable to conduct these exploratory analyses. Although these analyses detected moderate increases in theta power during ASMR, these differences were not statistically significant. One interpretation of these results is that ASMR does not influence theta activity. This conclusion would imply that ASMR is not as similar to mindfulness as was previously thought. An alternative interpretation is that ASMR is a heterogeneous phenomenon; for some people, ASMR may be a very mindful experience with increased present-moment awareness whereas for others, it may be associated with less attentive relaxation. This heterogeneity would reduce the effect sizes in experiments like the current study. Such a conclusion is largely consistent with survey studies, all of which report differences in ASMR intensity, triggers, and overall subjective experiences (e.g., Barratt & Davis, 2015; Fredborg et al., 2017). Future studies could test this “heterogeneity explanation” by obtaining objective and subjective assessments of present-moment awareness during an EEG study of ASMR.

An intriguing element of our results were related to the differences between audio and audiovisual stimuli. Although there were no statistical differences in the perceived intensity of the ASMR responses to these stimuli (as determined by post-experiment ratings), the EEG results were consistently more pronounced in the audio-only condition. This difference may be due to the fact that the audio condition involved an identical script for the ASMR and non-ASMR conditions, albeit with different speakers, whereas the ASMR videos differed both on semantic content and the person speaking. It is also possible that the visuals from ASMR videos direct attention away from the auditory component of the videos, which may be the most “potent” aspect of the ASMR audiovisual stimuli. The questions raised by the current results could be tested by having participants rate ASMR experiences for audiovisual, auditory-only, and visual-only presentations of the identical scene and script to determine ASMR tingle intensity differences across modalities.

13. Limitations

Although the current study provides novel information about the ASMR experience, there are some elements that could be

improved. The current study recruited a relatively small sample; a larger sample size would increase the power of these analyses, allowing more accurate estimations of the effects seen. A larger sample size would also have allowed us to test whether differences in self-reported ASMR intensity influenced the changes in brain activity; our current sample size precluded such an analysis. A second issue related to the sample is its homogeneity. Participants were mostly female Caucasian Canadians aged 18–37. Future research should examine the potential effects of participant sex, age, ethnicity, and cultural background to determine if these variables influence responses to ASMR stimuli. A final obstacle in the current study is EEG measurement itself. Several ASMR participants reported experiencing tingles during the EEG *set-up*; this response was due to the personal attention associated with measuring their head in order to fit the EEG cap and with applying the sensors. However, our system required electroconductive gel to be applied to each of the sensors prior to their application. Some participants reported that the EEG cap and gel interfered with their ability to experience tingling sensations in their scalp during our experiment. The EEG sensors measuring horizontal and vertical eye movements were reported as being particularly distracting. Future studies would likely benefit from the use of “dry” EEG systems.

An additional limitation of the current study is that the ASMR group performed a button press while the control group did not. Our primary aim was to ensure that the EEG analyses focused on the identical period of time for both the ASMR and Control groups. So, if an ASMR participant experienced tingling sensations at 2:15 of the video, his or her matched Control participant would have their brain activity measured at 2:15 as well. This would ensure that both the ASMR and Control participants experienced identical sensory and semantic input (e.g., they both would view 2:15 of a video). However, the fact that the ASMR participants pressed a button and the Control participants did not is problematic. One potential solution to the “button-press problem” would have been to tell the participant to press a button at a specific time (e.g., 2:15). However, doing so would have created an additional problem: how do you instruct the participant to do so? If we introduced a visual cue to press the button, this would have caused additional eye movements (which lead to a great deal of neural activity) in the Control participants but not in the ASMR participants. If we used an auditory cue to direct Control participants to press the button, then the Control participants would be experiencing an attentional orienting response while the ASMR participants did not. Therefore, rather than introducing potentially confounding variables into our procedure, we opted to simply have the Control participants passively view the videos.

14. Conclusions

The purpose of the current study was to expand on previous neuroimaging assessments of ASMR and, in so doing, delineate the precise changes in neural activity associated with this phenomenon. Previous survey studies indicated that ASMR involves a relaxed, flow-like state as well as sensorimotor tingling sensations. The current results are consistent with these reports, with changes in frontal-lobe alpha activity being linked with the cognitive/attentional element of ASMR and the sensorimotor rhythm and gamma-wave activity being associated with the tingling sensations. These results support the view that ASMR is a specific and measurable experience. They also highlight numerous avenues for further research into this interesting sensory-emotional phenomenon.

Author contributions

SDS, BKF, and AD designed the experiment. BKF conducted the experiment. KCJ analyzed the data. All authors contributed to the writing of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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