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Temporal integration and alpha oscillatory dynamics in individuals reporting persistent ESP-Like experiences

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A R T I C L E I N F O

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A B S T R A C T

Reports of Extrasensory Perception (ESP)-like experiences have been associated with altered temporal sensitivity, sense of agency, and alpha-band neural activity. However, evidence for these associations has been drawn largely from clinical or clinically enriched samples, limiting understanding of whether similar processes characterize individuals recruited outside explicitly clinical contexts who report persistent ESP-like experiences. The present study compared an ESP-like experience group, comprising individuals reporting persistent ESP-like experiences and no self-reported psychiatric diagnosis, with a non-ESP comparison group, comprising participants who did not report such experiences. Participants completed behavioural measures of temporal sensitivity (double-flash illusion) and sense of agency (judgement of agency), together with resting-state Electroencephalography (EEG) measures of posterior alpha power and Individual Alpha Frequency (IAF). A subset of participants in the ESP-like experience group also completed EEG during a self-reported active ESP-like state. Relative to the non-ESP comparison group, the ESP-like experience group showed reduced temporal sensitivity and a broader SoA window, consistent with broader temporal integration across perceptual and agentive domains. Resting-state EEG further revealed higher posterior alpha power and higher IAF in the ESP-like experience group. Multivariate analyses indicated that temporal sensitivity uniquely predicted group membership, whereas alpha measures explained shared, but not independent, variance. Exploratory within-participant analyses additionally suggested state-dependent modulation of alpha dynamics, with higher IAF during the active ESP-like state than during rest. These findings indicate that persistent ESP-like experiences in a sample recruited outside explicitly clinical contexts are associated with altered temporal integration and alpha-band dynamics.

1. Introduction

Reports of experiences interpreted as Extrasensory Perception (ESP) remain difficult to account for at the cognitive and neural levels. In the present study, ESP-like experiences refer to subjective experiences in which individuals believe they have acquired information or anticipated events without an apparent conventional sensory route. Rather than attempting to adjudicate between competing interpretations of such experiences, the present study examines whether ESP-like experiences are associated with differences in Sense of Agency (SoA), temporal sensitivity and alpha-band oscillatory activity.

The SoA refers to the subjective experience that one's actions or thoughts are self-generated and linked to their consequences (Chambon & Haggard, 2012). Experimental work suggests that SoA depends partly on temporal information, such that self-attribution declines as the delay between an action and its outcome increases (Erdoğan & Balcı, 2025; Farrer et al., 2013; Sato, 2009; Shimada et al., 2010). More broadly, research on self-monitoring suggests that disruptions in linking internal events to the self may alter source attribution in clinical populations (Shergill et al., 2000; Krugwasser et al., 2022). Although this does not imply that ESP-like experiences are equivalent to clinical symptoms, it suggests that individual differences in the temporal boundaries of agency may be relevant to experiences involving unusual source attribution.

A related construct is temporal sensitivity, often indexed by the Temporal Binding Window (TBW), defined as the interval within which sensory signals are likely to be integrated as belonging to the same event (Cecere et al., 2015; Watson, 1986). A broader TBW reflects reduced temporal sensitivity and greater tolerance for temporal discrepancy during multisensory integration. Prior work has further shown that TBW and SoA are closely related, with broader TBWs associated with broader SoA windows (Venskus et al., 2021). One possible explanation is that when events are integrated across a broader temporal interval, action outcomes remain eligible for self-attribution over longer delays.

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Reduced temporal sensitivity may therefore influence not only perceptual binding, but also the temporal boundaries within which actions and outcomes are experienced as causally linked. If individuals reporting ESP-like experiences are more likely to link events across broader temporal intervals, this should be observable at both perceptual and agentive levels.

Alpha oscillations provide a plausible neural correlate of these processes. Alpha-band activity has been linked to temporal sensitivity and the organisation of perceptual information over time (Gupta et al., 2025; Kononowicz & van Wassenhove, 2016; Marsicano et al., 2024; Treisman, 1963). Empirical studies indicate that Individual Alpha Frequency (IAF) predicts the width of the TBW, with higher IAF associated with narrower TBWs (Cecere et al., 2015; Venskus & Hughes, 2021). Consistent with this, Mioni et al. (2020) showed that modulation of IAF was associated with shifts in time perception, further supporting a role for IAF in subjective timing mechanisms. Alpha power has also been linked to agency-related processing, with Bu-Omer et al. (2021) showing that increases in parieto-occipital alpha and low-beta power were associated with reduced SoA. Together, these findings suggest that alpha-band dynamics are relevant to temporal sensitivity and agency-related processing, although the direction and specificity of these relationships may vary across tasks and populations. Both IAF and alpha power may therefore be relevant to processes associated with ESP-like experiences.

Despite these converging findings, an important gap remains. Most evidence linking altered temporal sensitivity, SoA and alpha dynamics to unusual perceptual experiences has come from clinical or clinically enriched samples, where such experiences often co-occur with broader psychiatric symptoms or related psychological characteristics (Haß et al., 2017; Krugwasser et al., 2022; Ramsay et al., 2021; Rossetti et al., 2026). This makes it difficult to determine whether the observed behavioural and neural differences are specifically related to ESP-like experiences or instead reflect other co-occurring factors. To begin to address this limitation, the present study compared an ESP-like experience group, comprising individuals reporting persistent ESP-like experiences, with a non-ESP comparison group drawn from the general population who did not report such experiences. Using behavioural measures of temporal sensitivity and SoA, together with resting-state EEG indices of posterior alpha power and IAF, the study tested whether the groups differed on these measures. A subset of participants in the ESP-like experience group also completed EEG during a self-reported active ESP-like experiential state. Based on prior work, group differences were expected in TBW, SoA window, posterior alpha power and IAF.

2. Method

2.1. Participants

Participants for the non-ESP comparison group were recruited through the University of Greenwich Sona Systems, a database of more than 2000 consenting participants. Eligibility for this group was determined using a study-specific self-report screening question asking whether participants had ever experienced ESP-like experiences. Participants were included in the non-ESP comparison group if they responded negatively to this question. This criterion was used to ensure that the comparison group did not self-report ESP-like experiences. Participants for the ESP-like experience group were recruited through local spiritual churches and colleges. For the purposes of this study, ESP-like experiences were defined as subjective experiences in which participants believed they had acquired information or anticipated events without an apparent conventional sensory route. Eligibility for the ESP-like experience group was determined using study-specific self-report screening questions. Participants were included if they responded affirmatively to a question assessing repeated extrasensory-type experiences, affirmatively to a question assessing whether such experiences had occurred on at least three separate occasions over a period of at least one year, negatively to a question assessing whether they offered paid psychic services, and negatively to a question assessing psychiatric diagnosis. The self-reported absence of psychiatric diagnosis was used to distinguish this sample from individuals recruited from explicitly clinical contexts. Intensity of ESP-like experiences was not assessed, and no validated measure of ESP-like experiences was administered. No structured diagnostic interview or validated measures of schizotypy, dissociation, absorption, hallucination proneness, or paranormal belief were administered.

A priori power analyses were conducted in G*Power 3.1. For the primary group comparisons between the ESP-like experience group and the non-ESP comparison group, power was estimated for independent-samples t-tests (two-tailed). Assuming a medium effect size ($d = 0.50$), an alpha level of 0.05, and 80% power, the required total sample size was $N = 128$ (64 participants per group). Power for the multivariable prediction of group membership was estimated using binary logistic regression. Assuming a medium effect corresponding to an odds ratio (OR) of 1.70, an alpha level of 0.05, and 80% power, the required total sample size was again $N = 128$. Because power in multivariable models depends on shared variance among predictors and the number of complete cases, this analysis was treated as secondary, and results are reported with odds ratios and 95% confidence intervals.

All participants had normal (or corrected to normal) vision and hearing to avoid these variables influencing the tasks. The local ethics committee approved the study, and participants gave their informed consent before taking part in the study. The study was conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and approved by the University of Greenwich‘s University Research Ethics Board. Data is made accessible on OSF via the following link: https://osf.io/e2b39/overview?view_only=88f14850526b408ca4b9cc4ef5fd9f72.

The final sample comprised 81 participants (ESP-like experience group: $n = 43$; non-ESP comparison group: $n = 38$). The non-ESP comparison group had a mean age of 26.37 years ($SD = 8.65$), whereas the ESP-like experience group was older on average, with a mean age of 36.81 years ($SD = 16.17$). In terms of gender distribution, the non-ESP comparison group included 9 males and 29 females, whereas the ESP-like experience group included 12 males and 31 females. Gender ratios were comparable across groups, with a predominance of female participants in both samples.

Due to task-specific exclusions (e.g., non-convergent psychometric fits) and EEG artefact rejection, sample sizes varied slightly across dependent measures. Specifically, SoA data were available for 68 participants (ESP-like experience group: 35; non-ESP comparison group: 33), TBW data for 69 participants (ESP-like experience group: 37; non-ESP comparison group: 32), and EEG measures (posterior alpha power and IAF) for 81 participants (ESP-like experience group: 43; non-ESP comparison group: 38). All analyses were conducted using all available data for each outcome variable.

2.2. Design

The study employed a between-groups design comparing the ESP-like experience group and the non-ESP comparison group. Group served as the independent variable. Multiple behavioural and neural measures were collected as dependent variables. SoA was assessed behaviourally using a judgement of agency task, quantified as the width of the SoA window, following the procedure described in Venskus et al. (2021). Temporal sensitivity was measured using the TBW derived from a double-flash illusion task, implemented in line with Venskus et al. (2023). Neural oscillatory activity was assessed via resting-state EEG, from which posterior alpha power and IAF were extracted, following established protocols (e.g., Cecere et al., 2015; Venskus & Hughes, 2021).

2.3. Measures

2.3.1. Judgement of agency task

The judgement of agency task was adapted from Farrer et al. (2013). The task was programmed and controlled by the INQUISIT Millisecond software package 5.0. Each trial started with a white fixation cross in the centre of the monitor. After a delay of 500 ms the fixation cross disappears, signalling the beginning of the trial. After the cross disappears, participants were asked to press the space bar on the computer keyboard whenever they want. Once participants pressed the key, a circle of 2.5 cm in diameter was displayed in the centre of the screen for 500 ms with 11 possible delays ranging from 0 ms to 1400 ms in steps of 140 ms. The task consisted of 2 blocks with each delay being presented 10 times in random order. In total participants completed 220 trials. Participants were required to judge if the appearance of the circle was caused by their button press, or if the computer had triggered the circle to appear. Participants were told that on some trials the computer would cancel their button press and re-trigger the appearance of the circle at a random interval. Participants were required to press key '1' if they thought that it was most likely they triggered the circle to appear and '2' if they thought that it was most likely computer triggered the circle to appear. This response approach was chosen over that of that of Farrer et al. (2013), where participants were given three choices (i.e. full control, partial control and no control), to avoid participants opting for the partial control if not fully sure. Such partial control responses would complicate the calculation of the time window of SoA, via the fitting of a sigmoid function. If the participants stated they felt they caused the appearance of the circle then they have experienced SoA. The delay of the appearance of the circle at which participant's judgements decline (according to sigmoid function) was taken as the width of their SoA window. (See Fig. 1)

2.3.2. Double-flash illusion

The double-flash illusion used was the same as that in the study of Cecere et al. (2015). We chose to use this version of the task, as it has previously been associated with individual differences in the EEG alpha peak frequency and successfully captured modulation by tACS (Cecere et al., 2015). The task was programmed and controlled by the INQUISIT Millisecond software package 5.0 (Millisecond Software, 2016) on an LCD monitor with a refresh rate of no less than 60 Hz. Visual and auditory stimuli were 33.3 ms in duration to ensure compatibility with majority of monitors (60 Hz refresh rate, 16.6 ms). Visual stimuli were in the form of a white circle with a diameter 1.32 cm located 1 cm below the fixation cross that was positioned in the centre of the screen. This stimulus setup was chosen as it has been shown that tasks involving multisensory integration are optimised when visual stimuli are displayed in peripheral vision (Shams et al., 2002). Auditory stimuli were in a form of a 3500 Hz pure tone presented via two typical PC stereo speakers. In order to minimise the possible effect of the spatial cues on the perception of the task, speakers were placed at each side of the monitor and raised to align with the position of the visual stimuli (Macaluso et al., 2004). Each trial begun with a white fixation cross in the centre of the monitor that remained on the screen throughout the trial. Stimulus Onset Asynchrony were between 32 ms and 208 ms, in steps of 16 ms. These particular Stimulus Onset Asynchronies were chosen to synchronize the stimulus timing with the refresh rate of the screen (60 Hz, 16.6 ms). Each Stimulus Onset Asynchrony was presented 28 times, for a total 308 trials. Participants were instructed to fixate on the fixation cross and report whether they perceived one or two flashes by pressing the key '1' or the key '2' respectively. If the second auditory stimulus occurs within the individual's TBW not just the first auditory stimulus is integrated with the visual stimulus but also the second auditory stimulus. This creates an illusion whereby participants report experiencing two flashes despite only one flash being presented. The stimulus onset asynchrony at which an individual no longer perceives two flashes is taken as the width of their TBW. (See Fig. 2)

2.3.3. Electroencephalography (EEG) recording

To measure IAF and alpha power, continuous resting-state EEG was recorded from an extended posterior region of interest (ROI) comprising electrodes O1, O2, Oz, POz, Pz, PO3, PO4, P3, and P4, mounted on an elastic cap (EasyCap) and acquired using a Brain Products BrainAmp DC system. Resting-state EEG was recorded for 2 min with eyes closed. The left mastoid served as the reference during recording. This posterior electrode cluster was selected because resting-state alpha activity is typically maximal over posterior scalp regions (Cecere et al., 2015; Venskus & Hughes, 2021).

2.4. Procedure

The study began online via Qualtrics. Participants were first presented with a Participant Information Sheet outlining the purpose and content of the study, the estimated time required, potential risks, confidentiality arrangements, and their right to withdraw. After providing Informed Consent, participants completed the inclusion screening questions and demographic items (i.e., age and gender). They were then instructed to download the INQUISIT software and complete the judgement of agency task and the double-flash illusion task. Following completion of the behavioural tasks, resting-state EEG data were recorded. Finally, participants received a debrief.

2.5. Analysis

2.5.1. Judgement of agency task

SoA was explored via SoA window determined by the judgement of agency task. The number of times the individual reported that they caused the circle to appear on the screen was recorded for each delay. Thereafter, a sigmoid function was fitted to the data, determining each participant's inflection point (corresponding to the width of the SoA window), in ms. A sigmoid function was used to fit the distribution of responses and was defined by the equation: $y = a + b/(1 + \exp(-(x\text{-}c)/d))$ (a = upper asymptote; b = lower asymptote; c = inflection point; d =

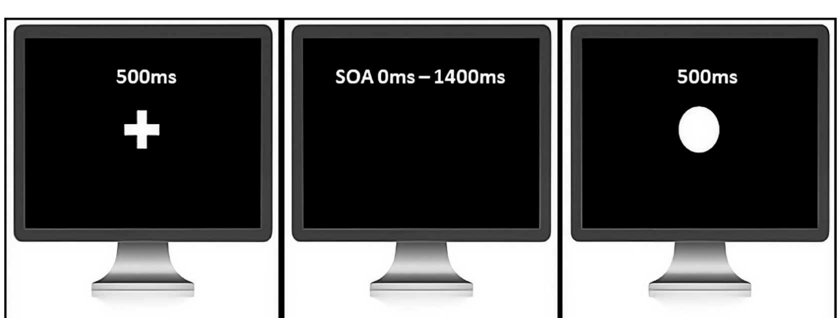

Fig. 1. Paradigm of the judgement of agency task.

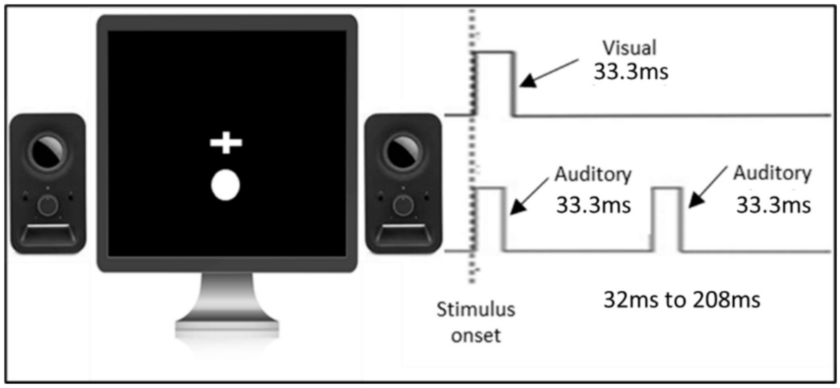

Fig. 2. Paradigm of the double-flash illusion task.

slope). For each participant, c was taken as the SoA window, i.e. the point of decay of the self-attribution (Sato, 2009; Shimada et al., 2010). SoA window values (in ms) were used as the dependent measure in subsequent statistical analyses.

2.5.2. Double-flash illusion

To assess temporal sensitivity the width of the TBW was measured via double-flash illusion. To measure the width of the TBW, the time window in which the illusion was maximally perceived, the percentage of trials where two flashes were reported was first plotted as a function of the inter-beep delay. A psychometric sigmoid function was then fitted to the data. The sigmoid function was defined by the equation: $y = a + b/(1 + \exp(-(x\text{-}c)/d))$ (a = upper asymptote; b = lower asymptote; c = inflection point; d = slope). For each participant, c was taken as the TBW, i.e. the point of decay of the illusion (Cecere et al., 2015). TBW values (in ms) were used as the primary index of temporal sensitivity in subsequent analyses.

2.5.3. Alpha oscillations

Resting-state EEG data were processed in EEGLAB (Delorme & Makeig, 2004) using a preprocessing pipeline designed to support robust estimation of alpha-band activity. Continuous EEG data were filtered, cleaned for artefacts, re-referenced, epoched, and corrected for ocular components using independent component analysis. Analyses focused on an extended posterior region of interest (O1, O2, Oz, POz, Pz, PO3, PO4, P3, and P4), reflecting the posterior dominance of resting-state alpha activity (Cecere et al., 2015; Venskus & Hughes, 2021). Power spectra were computed for each participant, and two alpha metrics were extracted from the ROI-averaged spectrum: IAF, defined as the frequency of the maximum spectral peak within the 7–14 Hz range, and alpha power, defined as the mean power across the 7–14 Hz band. Full preprocessing and spectral analysis details are provided in the Supplementary Materials.

2.6. Statistical analysis

All statistical analyses were conducted using MATLAB and SPSS. Statistical significance was assessed using a two-tailed alpha level of 0.05.

Descriptive statistics (means and standard deviations) were computed separately for the ESP-like experience group and the non-ESP comparison group for each dependent variable: SoA window, TBW, alpha power, and IAF. Data distributions were inspected visually, and assumptions of normality and homogeneity of variance were evaluated using Shapiro–Wilk and Levene's tests, respectively. Where violations of homogeneity of variance were observed, Welch-corrected tests were applied.

Group differences were examined using independent-samples t-tests, conducted separately for each dependent variable using all available data. Effect sizes are reported as Hedges' g. Given the a priori nature of the outcome measures, statistical inference was based on uncorrected p-values, with results additionally evaluated using false discovery rate (FDR) correction.

To examine whether temporal sensitivity, SoA, and alpha oscillatory measures jointly predicted group membership, a binary logistic regression was conducted with group (ESP-like experience group vs non-ESP comparison group) as the dependent variable. TBW, SoA window, posterior alpha power and IAF were entered simultaneously as predictors. Predictors were z-standardised prior to analysis. Model fit was assessed using likelihood ratio tests and pseudo-R^2 indices, and results are reported as odds ratios with 95% confidence intervals.

Due to task-specific exclusions and EEG artefact rejection, sample sizes varied across measures. Analyses were conducted using pairwise deletion, such that each analysis included all participants with valid data for the relevant variables.

2.7. Additional EEG recording during ESP-like experiences

A separate subgroup from the ESP-like experience group (n = 15), who did not complete the behavioural tasks, participated in an additional EEG-only session. Following a resting-state EEG recording, participants completed a further 3-minute EEG recording during which they were instructed to relax and attempt to perceive sensory information via ESP. All participants included in this analysis reported experiencing ESP-like phenomena during the recording period. EEG acquisition, preprocessing, and spectral analysis procedures were identical to those used for the resting-state EEG recordings described above. This additional recording allowed a within-participant comparison of alpha oscillatory activity between resting state and a self-reported active ESP-like experiential state.

3. Results

3.1. Data screening and assumption checks

Prior to hypothesis testing, distributions of SoA window, TBW, alpha power, and IAF were inspected using histograms and Q–Q plots. Although Shapiro–Wilk tests indicated some deviations from normality for TBW, alpha power, and IAF, visual inspection suggested no extreme departures from normality, and sample sizes were sufficient for parametric analyses, given the robustness of t-tests under moderate non-normality. Homogeneity of variance was assessed using Levene's test. This assumption was violated for TBW, and therefore Welch-corrected t-tests were used for this measure. For SoA, alpha power, and IAF, homogeneity of variance was not violated, and standard independent-samples t-tests were applied. Outliers were evaluated using standardised scores and visual inspection. No extreme outliers were identified beyond cases reflecting clear measurement failure (e.g., non-convergent psychometric fits or unusable EEG following preprocessing), which were excluded at the task level as described in the Methods.

3.2. Descriptive statistics

(See Table 1 andFig. 3)

3.3. Sense of agency window

Group differences in SoA were examined using an independent-samples *t*-test. Homogeneity of variance was not violated for SoA (Levene's test, p = 0.071), and therefore a standard *t*-test was applied. The ESP-like experience group showed a significantly wider SoA window than the non-ESP comparison group (M = 823.20 ms, SD = 273.01 vs. M = 518.52 ms, SD = 200.60), t(66) = 5.22, p < 0.001, Hedges' g = 1.25.

3.4. Temporal binding window

Temporal sensitivity was indexed by the width of the TBW derived from the double-flash illusion. Inspection of assumptions indicated that homogeneity of variance was violated for TBW (Levene's test, p = 0.010); therefore, a Welch-corrected independent-samples *t*-test was applied. The ESP-like experience group showed a significantly wider TBW than the non-ESP comparison group (M = 141.49 ms, SD = 44.40 vs. M = 81.47 ms, SD = 30.59), Welch's t(63.98) = 6.61, p < 0.001, Hedges' g = 1.54.

3.5. Alpha power (7–14 Hz)

Posterior alpha power differed significantly between groups. Homogeneity of variance was met for alpha power (Levene's test, p = =.15), and therefore a standard independent-samples *t*-test was applied. The ESP-like experience group showed higher alpha power than the non-ESP comparison group (M = 0.73, SD = 0.18 vs. M = 0.62, SD = 0.26), t (79) = 2.21, p = =.030, Hedges' g = 0.49.

3.6. Individual alpha frequency (IAF)

Group differences in individual IAF were examined using an independent-samples *t*-test. Homogeneity of variance was met for IAF (Levene's test, p = 0.28), and therefore a standard *t*-test was applied. The ESP-like experience group showed a significantly higher IAF than the non-ESP comparison group (M = 10.55 Hz, SD = 1.06 vs. M = 9.42 Hz, SD = 1.14), t(79) = 4.65, p < 0.001, Hedges' g = 1.03.

3.7. Multivariate prediction of group membership

To examine whether temporal sensitivity, SoA, and alpha oscillatory measures jointly predicted group membership (ESP-like experience group vs. non-ESP comparison group), a binary logistic regression was conducted. Group was entered as the dependent variable (0 = non-ESP comparison group, 1 = ESP-like experience group), and TBW, SoA window, posterior alpha power, and IAF were entered simultaneously as predictors. Analyses were conducted on participants with complete data across all variables (N = 62). The overall model was statistically significant, $\chi^2(4) = 38.97$, $p < 0.001$, indicating that the predictor set reliably distinguished between groups. The model explained a substantial proportion of variance in group membership ($R^2 = 0.45$) and demonstrated good classification performance. At the individual predictor level, TBW emerged as a significant unique predictor, such that wider TBWs were associated with increased odds of belonging to the ESP-like experience group (OR = 1.04, 95% CI [1.01, 1.07], p = 0.006). Neither SoA window (p = 0.103) nor posterior alpha power (p = 0.519) independently predicted group membership when controlling for the other variables. IAF showed a trend-level association with group membership (OR = 2.49, 95% CI [0.93, 6.71], p = 0.071), suggesting that higher IAF may contribute to group differentiation, although this effect did not reach conventional significance in the multivariable model.

Table 1
Descriptive statistics for behavioural and EEG measures.

Measure	ESP-like experience group (N, M, ± SD)	Non-ESP comparison group (N, M, ± SD)
Sense of Agency Window (ms)	35, 823.20, ± 273.01	33, 518.52, ± 200.60
Temporal Binding Window (ms)	37, 141.49, ± 44.40	32, 81.47, ± 30.59
Alpha Power (dB)	43, 0.73, ± 0.18	38, 0.62, ± 0.26
Individual Alpha Frequency (Hz)	43, 10.55, ± 1.06	38, 9.42, ± 1.14

Note. Sense of Agency (SoA) window and Temporal Binding Window (TBW) values represent inflection points (parameter c) derived from sigmoid fits computed in MATLAB. Ns may vary across measures.

3.8. Additional EEG analysis during ESP-like experiences

To explore state-dependent modulation of alpha oscillatory activity during self-reported ESP-like experiences, alpha power and IAF were compared between resting state and the active ESP-like recording within the EEG-only subgroup from the ESP-like experience group (n = 15). (See Table 2 and Fig. 4)

Prior to analysis, distributions of the IAF and alpha power difference scores were inspected using histograms and Q–Q plots. No extreme departures from normality were observed. Given the within-subject design and the robustness of paired-samples t-tests to modest deviations from normality, parametric tests were deemed appropriate.

A paired-samples *t*-test revealed a significant increase in IAF during the active ESP-like state relative to rest. IAF was higher during the ESP condition (M = 10.22 Hz, SD = 1.25) than during resting state (M = 9.44 Hz, SD = 0.98), t(14) = 2.35, p = 0.034, indicating a shift toward faster IAF during the active ESP-like state.

A paired-samples *t*-test indicated a trend toward reduced posterior alpha power during the active ESP-like state compared with rest. Alpha power was lower during the ESP condition (M = 0.62, SD = 0.19) than during resting state (M = 0.67, SD = 0.17); however, this difference did not reach conventional statistical significance, t(14) = − 2.08, p = 0.057.

4. Discussion

The present study examined whether temporal sensitivity, SoA and alpha oscillatory dynamics differed between the ESP-like experience group and the non-ESP comparison group. Across behavioural measures, the ESP-like experience group showed both a broader TBW and a broader SoA window than the non-ESP comparison group. At rest, the ESP-like experience group also showed higher posterior alpha power and IAF. In the multivariate analysis, TBW emerged as the strongest unique predictor of group membership, whereas alpha measures contributed shared but not independent variance. In exploratory within-participant analyses, IAF increased during a self-reported active ESP-like state, whereas alpha power showed a non-significant reduction. Taken together, these findings indicate that, in the present sample, the ESP-like experience group showed broader temporal integration across perceptual and agentive domains, alongside altered alpha-band dynamics. Overall, the findings point to differences in temporal and agency-related processing in individuals reporting persistent ESP-like experiences. However, the results should be interpreted cautiously given the study's methodological limitations.

4.1. Temporal sensitivity and group differences

TBWs than the non-ESP comparison group, indicating reduced

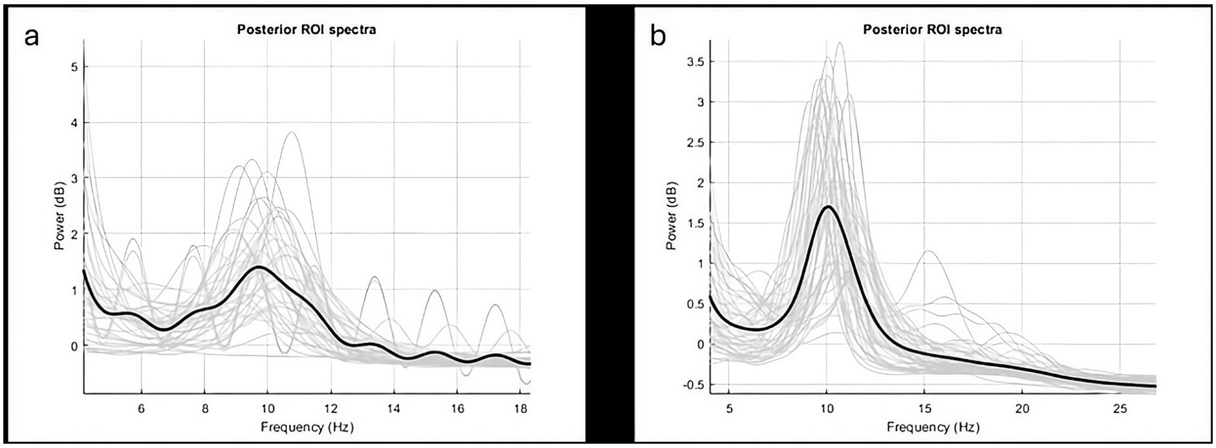

Fig. 3. Posterior Region-of-Interest (ROI) power spectra during resting state for the non-ESP comparison group (a) and the ESP-like experience group (b). The solid black line represents the grand-average resting-state spectrum. Spectra were averaged across posterior ROI channels (O1, O2, Oz, POz, Pz, PO3, PO4, P3, and P4) and across participants. Grey lines represent individual participant spectra.

Table 2
Descriptive statistics for behavioural and EEG measures.

Measure	ESP-like experience group: rest (N, M, ± SD)	ESP-like experience group: during (N, M, ± SD)
Alpha Power (dB)	15, 0.67, ± 0.17	15, 0.62, ± 0.19
Individual Alpha Frequency (Hz)	15, 9.44, ± 0.98	15, 10.22, ± 1.25

temporal precision in multisensory integration. This finding is consistent with previous work linking wider TBWs to broader perceptual integration windows and reduced temporal resolution (Cecere et al., 2015; Venskus et al., 2023). One implication of a broader TBW is that sensory events separated by longer temporal intervals may still be experienced as belonging to the same event. Such increased temporal tolerance may, in turn, promote a greater tendency to perceive connections or correspondences between events that would otherwise be treated as separate. The multivariate analysis further indicated that TBW was the strongest unique predictor of group membership. This suggests that temporal sensitivity may be particularly important in distinguishing the ESP-like experience group from the non-ESP comparison group in the present sample. However, the specificity of this association remains uncertain. Accordingly, the present findings are best interpreted as indicating that broader temporal integration was more evident in the ESP-like experience group than in the non-ESP comparison group in the present sample.

4.2. Sense of agency and group differences

The groups also differed significantly in SoA, with the ESP-like experience group showing a broader SoA window than the non-ESP comparison group. This indicates that action outcomes continued to be attributed to the self over longer delays. In the present framework, however, this should not be interpreted as enhanced agency. Rather, a broader SoA window is more appropriately interpreted as reduced temporal precision in agency attribution, such that outcomes remain eligible for self-attribution across a wider temporal interval. Interpreted in this way, the finding is consistent with previous work showing that agency judgements depend on the temporal relationship between actions and their effects (Erdoğan & Balcı, 2025; Farrer et al., 2013; Venskus et al., 2021). It also complements the TBW findings by suggesting that broader temporal integration in the ESP-like experience group may extend beyond perceptual binding to higher-order judgements of action and authorship. When events are integrated across broader temporal intervals, action outcomes may remain eligible for

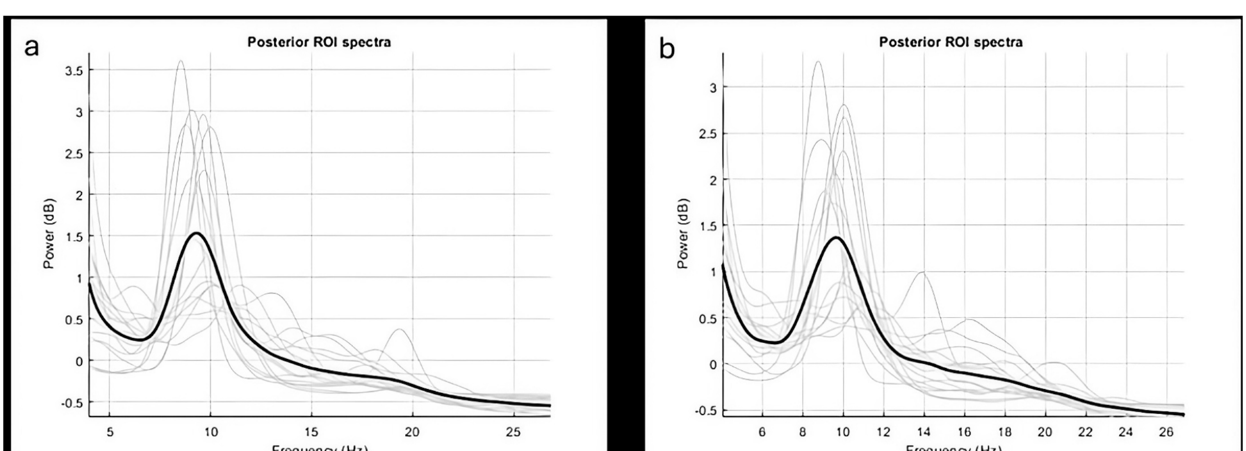

Fig. 4. (a) Posterior Region-of-Interest (ROI) power spectra during resting state in the ESP-like experience group. The solid black line represents the grand-average resting-state spectrum. Spectra were averaged across posterior ROI channels (O1, O2, Oz, POz, Pz, PO3, PO4, P3, and P4) and across participants. Grey lines represent individual participant spectra. (b) Posterior ROI power spectra during the self-reported active ESP-like state in the ESP-like experience group. The solid black line represents the grand-average spectrum during the active ESP-like state. Spectra were averaged across posterior ROI channels (O1, O2, Oz, POz, Pz, PO3, PO4, P3, and P4) and across participants. Grey lines represent individual participant spectra.

self-attribution over longer delays. Reduced temporal precision may therefore influence not only perceptual binding, but also the temporal boundaries within which actions and outcomes are experienced as causally linked, consistent with the relationship between TBW and SoA reported by Venskus et al. (2021). However, SoA did not uniquely predict group membership once TBW and alpha measures were included in the multivariate model. This pattern suggests that SoA may not function as an independent marker in the present sample but may instead reflect variance shared with broader temporal integration processes. Accordingly, the present findings suggest that agency-related differences formed part of the broader profile observed in the ESP-like experience group, although the specificity of this association remains uncertain.

4.3. Alpha dynamics and group differences

The present study also found that the ESP-like experience group showed higher resting-state posterior alpha power and higher IAF than the non-ESP comparison group. These findings indicate that group differences were evident not only at the behavioural level but also in ongoing alpha-band dynamics. Alpha oscillations were examined because prior work has linked them to temporal sensitivity, subjective timing, and agency-related processing (Bu-Omer et al., 2021; Cecere et al., 2015; Gupta et al., 2025; Kononowicz & van Wassenhove, 2016; Marsicano et al., 2024; Mioni et al., 2020). However, the direction of the present alpha findings did not map straightforwardly onto expectations derived from that literature.

Previous work has linked higher IAF to narrower TBWs and greater temporal precision (Cecere et al., 2015; Venskus & Hughes, 2021). In the present study, by contrast, the ESP-like experience group showed higher resting-state IAF alongside broader TBWs and broader SoA windows relative to the non-ESP comparison group. This pattern is not straightforwardly consistent with prior findings and indicates that the relationship between IAF and behavioural measures was more complex in the present sample than might have been expected. Because these findings are based on between-group differences rather than direct within-sample associations, they do not establish a simple relationship between IAF and behavioural measures in the present dataset. Instead, they suggest that the relationship between IAF and behavioural indices of temporal integration may not generalise straightforwardly to this sample, or that IAF and behavioural measures may index partially distinct aspects of processing.

A similar issue applies to alpha power. Prior work has linked posterior alpha power to agency-related processing, with increased parieto-occipital alpha and low-beta power associated with reduced SoA (Bu-Omer et al., 2021). In the present study, the ESP-like experience group showed higher resting-state posterior alpha power while also showing a broader SoA window. Although this pattern is broadly consistent with altered agency-related processing, it does not support a simple or uniform account of alpha power in relation to SoA. As with IAF, the present findings suggest that posterior alpha power may reflect aspects of ongoing neural processing that do not map directly onto the behavioural indices examined here.

The multivariate results further support a cautious interpretation. Posterior alpha power did not uniquely predict group membership when the behavioural measures were included, and IAF showed only a trend-level contribution. Thus, although alpha measures differentiated the groups at the univariate level, they did not make strong independent contributions once shared variance with behavioural measures was taken into account. Taken together, these discrepancies suggest that altered alpha-band dynamics formed part of the broader profile observed in the ESP-like experience group, but do not support a simple or independent link between alpha measures and self-reported ESP-like experiences in the present sample.

4.4. State-dependent alpha dynamics during ESP-like experiences

The exploratory within-participant EEG analysis provides preliminary evidence that alpha dynamics may also vary as a function of self-reported experiential state. In the EEG-only **subgroup** from the ESP-like experience group, IAF increased during the active ESP-like state relative to rest, whereas alpha power showed a non-significant reduction. This pattern suggests that alpha-band activity may be modulated during attempts to engage in an ESP-like state, rather than reflecting only a stable resting-state group difference. These findings should, however, be interpreted with caution. The subgroup was small, the active state was defined by self-report rather than by an objective marker, and no behavioural or physiological measure was available to verify the nature or intensity of the reported state. Accordingly, this within-participant EEG analysis should be regarded as exploratory and hypothesis-generating rather than confirmatory. Nevertheless, the observation of state-related variation complements the resting-state findings and suggests that alpha dynamics may reflect not only between-group differences, but also within-participant changes associated with self-reported ESP-like states.

4.5. Limitations and future directions

Several limitations should be acknowledged. First, the ESP-like experience group was defined on the basis of self-reported ESP-like experiences and self-reported absence of psychiatric diagnosis, rather than structured diagnostic interview or validated symptom screening. The sample was therefore recruited outside explicitly clinical contexts, but the study did not establish the absence of clinically relevant or subclinical features. In addition, ESP-like experiences were identified using study-specific self-report screening rather than a validated measure, and their intensity was not assessed. The study also did not include validated measures of schizotypy, dissociation, absorption, hallucination proneness, or paranormal belief. These limitations are important because such factors may relate both to anomalous experience reports and to the cognitive and electrophysiological measures examined here, meaning that the observed group differences cannot be assumed to reflect self-reported ESP-like experiences specifically. At the same time, the study remains informative in showing that this pattern of behavioural and alpha-band differences was observed in a sample of individuals reporting persistent ESP-like experiences recruited outside explicitly clinical settings.

Second, sample sizes varied across measures because of task-specific exclusions and EEG artefact rejection, and the multivariate model was based only on participants with complete data across all predictors. Although this approach allowed the use of all available data for each analysis, it reduced precision and may have affected the stability of some estimates, particularly in the multivariable analysis. Nevertheless, convergent group differences were observed across multiple behavioural and electrophysiological measures, which increases confidence that the findings do not depend on a single outcome alone.

Third, the exploratory EEG analysis during the active ESP-like state was based on a relatively small subgroup and should therefore be interpreted cautiously. The subgroup analysis should be regarded as preliminary and hypothesis-generating rather than confirmatory. Even so, it provides an initial indication that alpha dynamics may vary not only between groups at rest, but also across self-reported experiential states within participants reporting persistent ESP-like experiences.

A further limitation is that the ESP-like experience group was older on average than the non-ESP comparison group. Although age was not the primary focus of the present study, age-related differences in perceptual and electrophysiological measures cannot be ruled out and may have contributed to some of the observed between-group effects. This is particularly relevant because the present study examined temporal integration, agency and alpha-band measures, all of which may vary with age (De Dieuleveult et al., 2017; Scally et al., 2018; Wolpe et al., 2016). Accordingly, the between-group findings should be interpreted with caution. This concern does not apply in the same way to the exploratory within-participant EEG comparison, in which resting state and active ESP-like state were compared within the same individuals.

Given these limitations, future studies should aim to match groups more closely on age or include age as a covariate in larger samples. Future work should also combine behavioural and electrophysiological measures with structured clinical screening and validated assessments of schizotypy, dissociation, absorption, hallucination proneness, and paranormal belief. This will be important for determining whether the present effects remain after accounting for these related factors, and for clarifying the extent to which altered temporal integration and alpha dynamics are specifically associated with self-reported ESP-like experiences.

4.6. Conclusions

In conclusion, the present study identified behavioural and electrophysiological differences between the ESP-like experience group and the non-ESP comparison group across measures of temporal sensitivity, SoA and alpha-band dynamics. Relative to the non-ESP comparison group, the ESP-like experience group showed a broader TBW, a broader SoA window, and higher resting-state posterior alpha power and IAF. Across analyses, temporal sensitivity emerged as the strongest unique predictor of group membership, whereas SoA did not make an independent multivariable contribution and alpha measures showed group-level differences together with preliminary state-related modulation. Taken together, these findings suggest that, in the present sample, the ESP-like experience group was characterised by broader temporal integration across perceptual and agentive domains, alongside altered alpha-band dynamics. However, because relevant clinical and subclinical traits were not formally assessed, because the groups differed in age, and because the alpha findings did not map straightforwardly onto prior expectations, the specificity and interpretation of these effects remain to be established.

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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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2026.104059.

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