

# Association between changes in EEG alpha power and behavioural outcome in autistic children induced by child-centred play therapy: A randomised controlled trial

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## Abstract

**Objective:** The traditional research on evaluating psychological interventions has primarily relied on behavioural measurements (e.g. self-report questionnaires). This study aimed to investigate the effects of child-centred play therapy (CCPT) on autistic children at both behavioural and neural levels, as well as the association between the changes in neural and behavioural measurements induced by CCPT. It is hypothesised that alpha power would increase after CCPT, along with improvements in social responsiveness, adaptive social behaviour and autism spectrum disorder (ASD) social symptom measures and that these changes would be correlated across participants.

**Method:** A total of 65 autistic children were randomly assigned to a CCPT experimental group ( $n=34$ ;  $M$  age=7.50) or a waitlist control group ( $n=31$ ;  $M$  age=7.47). Electroencephalography (EEG) alpha power and behavioural data were recorded during pre- and post-intervention assessment sessions. The behavioural measurements included the Social Responsiveness Scale-2, Autism Spectrum Quotient–Child (social skill subscale) and Adaptive Behaviour Assessment System-II (social domain).  $t$ -Tests and correlational analyses were conducted to examine the CCPT effects and brain-behaviour associations.

**Results:** The results confirmed the effects of CCPT at both neural and behavioural levels and the association between these two levels across participants. Specifically, individuals with larger increases in alpha power after CCPT also showed greater behavioural improvement.

**Conclusion:** This study marks an initial endeavour, providing the first cross-validation of CCPT effects on autistic children by demonstrating the brain-behaviour association. This approach advances the understanding of the therapeutic intervention effects of CCPT by presenting its multilevel impacts.

## KEYWORDS

alpha power, autism spectrum disorder, electroencephalography, play therapy, social behaviour

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## 1 | INTRODUCTION

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterised by persistent difficulties in social communication and interaction, alongside restricted, repetitive behaviours, interests or activities (American Psychiatric Association, 2013). Autistic children often face significant social challenges, which are frequently the focus of therapeutic interventions aimed at enhancing their quality of life (Blalock et al., 2019; Hillman, 2018).

Child-centred play therapy (CCPT) is a nondirective therapeutic approach that allows children to guide the content, process and themes of play during therapy sessions (Landreth, 2012). In CCPT, therapists create a safe and accepting environment where children can freely express themselves, which helps in emotional expression, self-esteem enhancement and self-regulation (Landreth, 2012). CCPTs focus on the child's autonomy and natural mode of communication—play—makes it particularly effective for autistic children, who may find traditional verbal therapies challenging (Schottelkorb et al., 2020).

Supporting research indicates that CCPT can lead to improvements in social and emotional competencies, as well as reductions in externalising behaviours in children, including those with ASD (Guest & Ohrt, 2018; Lin & Bratton, 2015; Schottelkorb et al., 2020). Despite the proven efficacy of CCPT, the evaluation of its impact has largely focussed on behavioural outcomes (Kazdin & Nock, 2003; Schottelkorb et al., 2020). This approach, while insightful, often lacks a robust cross-validation of the intervention outcomes and a comprehensive understanding of intervention effects (Boateng et al., 2018).

To remedy this, the integration of neural indicators, such as brain-wave activity, into the evaluation process is receiving growing attention (Brush et al., 2022; Gilam et al., 2017; Harmer, 2014). By capturing changes in brain activity directly related to intervention effects, the neural data potentially offer an additional facet of information about the intervention outcomes that is complementary to the behavioural data for evaluating the intervention and informing the design.

Electroencephalography (EEG) spectrum power is a metric that is increasingly utilised for assessing the impact of psychological interventions. Its utility is seen in various studies that have used it to evaluate the effects of psychological interventions on neurotypical individuals (Chow et al., 2017; Khng & Mane, 2020) and those with diverse neurological conditions, such as attention-deficit hyperactivity disorder (Egner & Gruzelier, 2001), depression (Carvalho et al., 2020) and obsessive compulsive disorder (Hawley et al., 2021). Of the various frequencies of brainwaves, the EEG alpha wave has been shown to be a sensitive neural indicator of changes in social cognitive states, such as relaxation, meditation and mind wandering (Braboszcz & Delorme, 2011; Buzsaki & Draguhn, 2004). Decreases in alpha power are linked with increased social cognitive workload, attention and task engagement (Klimesch et al., 2007). It can thus provide insights into the generic states of relaxation associated with various behavioural patterns related to interventions (Klimesch, 1999).

A significant advantage of using EEG alpha power as a neural marker lies in its predictive capacity for individual differences (Grandy et al., 2013; Haegens et al., 2014). Spontaneous alpha

### Implications for Practice and Policy

- With a deeper understanding of how CCPT influences brain activity in autistic children, both therapists and parents can make more informed decisions regarding the use of CCPT as a therapeutic intervention. This knowledge empowers stakeholders to select interventions that are not only effective at a behavioural level but also beneficial in terms of neurological development.
- Incorporating EEG monitoring into therapeutic sessions offers a comprehensive view by capturing real-time neurological responses alongside behavioural changes in autistic children. This dual tracking enables therapists and stakeholders, including parents, to cross-validate the outcomes of interventions, ensuring a holistic understanding of the child's progress.
- Therapists and practitioners should be updated with the latest research findings, particularly regarding the neurological effects of CCPT on autistic children. Training programmes should be aimed at enhancing their capabilities in integrating these findings into therapeutic practices. Such professional development initiatives will broaden their understanding of CCPT's impact on brain activity, facilitating informed decisions in potentially tailoring therapy to meet individual needs effectively.
- Policymakers should advocate for the inclusion of CCPT as an endorsed intervention within autism care guidelines, emphasising its evidence-based benefits at both behavioural and neurological levels. Funding and resources should be allocated to support training for therapists in CCPT techniques and the integration of EEG monitoring in therapeutic settings to ensure a high standard of care.

oscillations in ASD have also provided evidence of decreased alpha power in ASD compared with typically developing groups (Chan et al., 2007; Dickinson et al., 2018; Sheikhan et al., 2012). Moreover, EEG alpha power exhibits alterations in relation to different psychological interventions, including meditation (Lagopoulos et al., 2009), neurofeedback (Kober et al., 2015) and cognitive training (Maggioni et al., 2019). This alteration not only serves as a measure of the effectiveness of these interventions but also provides critical insights into how these practices influence brain functionality and behaviour. Consequently, EEG alpha power is identified as a viable tool to assess outcomes of interventions. In particular, it can discern individual differences and subsequently facilitate cross-validation of intervention outcomes.

Despite the wealth of information that EEG alpha frequency power provides about various psychological interventions and their impacts, most research has centred on directive interventions, such

as cognitive therapy (Magosso et al., 2019) and mindfulness training (Lagopoulos et al., 2009). Consequently, the neurological implications of nondirective interventions, such as CCPT, have remained largely unexplored, leading to a lack of cross-validation of intervention outcomes and an absence of precise, accurate measures of intervention effects (Boateng et al., 2018). Existing studies have primarily focussed on the overall effects of these interventions without exploring individual differences between pre- and post-intervention stages.

To better understand the neural dynamics, we designed conditions for EEG measurement involving the presence of a parent, a stranger or the child being alone. This design is based on the existing literature that suggests the social context can significantly influence neural activity. For instance, the presence of a familiar person (parent) versus an unfamiliar person (stranger) or being alone can differentially impact the child's neural responses and social behaviour (Verbeke et al., 2014; Zajonc, 1965). By examining these conditions, we aim to elucidate how different social contexts affect the therapeutic process and outcomes of CCPT.

In an effort to address this research gap, this study aimed to investigate the impact of CCPT on autistic children by employing EEG alpha power as a neural marker. Specifically, the study will explore the correlation between changes in individual alpha power and alterations in behavioural measurements before and after CCPT in autistic children. Given the established relaxation association of alpha power as documented in the existing literature, it is hypothesised that alpha power will increase in children in the experimental group during social situations following CCPT. This increase in alpha power is expected to correlate with improvements in the behavioural data gathered through various questionnaires. More specifically, this suggests that a greater increase in alpha power may be associated with more significant improvements as reflected by the questionnaires.

To the best of our knowledge, this study represents the first attempt to examine the correlation between changes in alpha power and alterations in behavioural measurements pre- and post-CCPT in autistic children. As such, it presents a pioneering effort in integrating neurological markers into the evaluation of this therapeutic intervention's effects, thereby providing a cross-validation mechanism and promoting a more comprehensive understanding of its impact on autistic children.

## 2 | METHODS

### 2.1 | Trial design

This study expanded upon the initial research using a randomised controlled trial that included a CCPT experimental group and a waitlist control group. The Human Research Ethics Committee [EA210015] of [The University of Hong Kong] granted approval. Prior to commencing the experiment, written assent was obtained from the child participants and written consent from their parents.

### 2.2 | Participants

In the study, 82 autistic children enrolled (Figure 1). After an assessment of eligibility, 68 of these children met the criteria and were randomly allocated to either the experimental (EXP;  $n=34$ ) or waitlist (WL;  $n=34$ ) group.

To be eligible for participation in this study, children had to meet certain criteria, including the following: (a) being between 6 and 10 years old; (b) possessing both a verbal and full-scale IQ of 70 or greater on the Wechsler Intelligence Scale for Children—Fifth Edition (WISC-V; Wechsler, 2014); (c) attending primary school; (d) having no other neural or physical impairments; (e) having no other history of major mental illnesses or medical conditions; (f) being a native Cantonese speaker; (g) having an ASD diagnosis from registered psychologists or psychiatrists based on the criteria of DSM-5 (American Psychiatric Association, 2013); (h) scoring 76 or above on the Autism Spectrum Quotient—Children's Version (AQ-Child; Auyeung et al., 2008); and (i) being able to attend eight CCPT sessions. After withdrawals, the EXP group consisted of 34 participants, while the WL group had 31 participants. There were no significant differences in sociodemographic and clinical characteristics between the groups (Table 1).

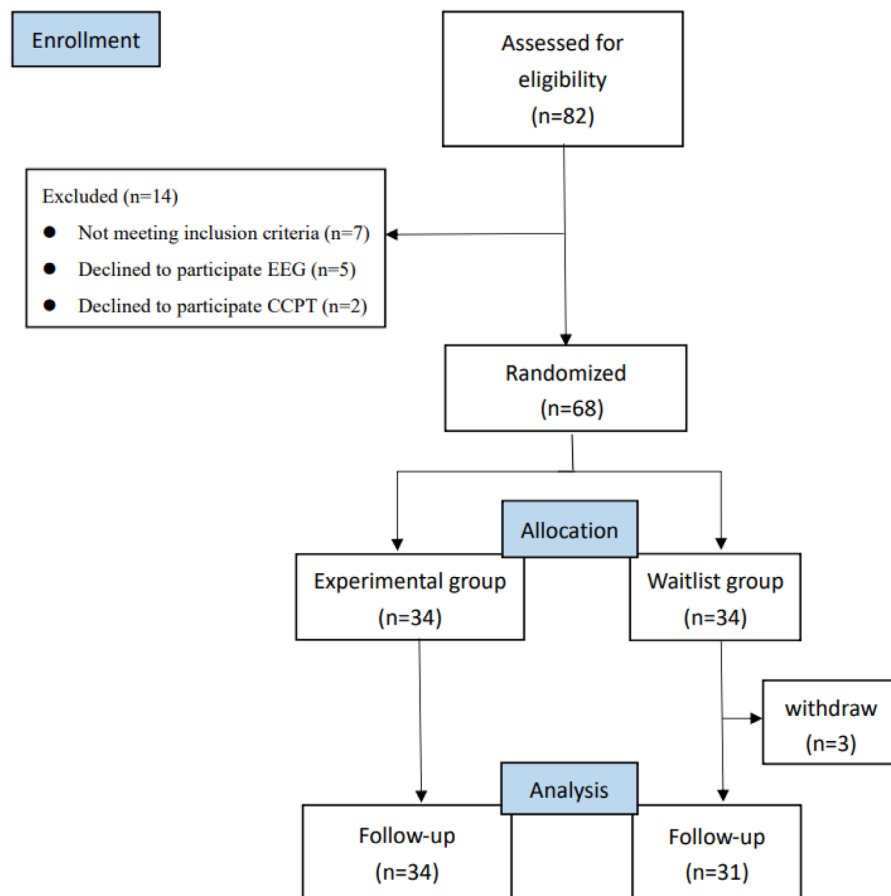
### 2.3 | Procedures

From March to December 2021, participants were recruited through local non-profit autism organisations and community advertisements. Interested parents completed an online application and screening questionnaire, which included study details, consent and contact information. An independent researcher used a digital random number generator to assign participants to the WL or EXP group. The first author was informed of the randomisation and communicated it to the participants. Upon successfully completing both pre- and post-intervention assessment sessions, participants from the EXP and WL groups were each rewarded with an incentive of HK\$300.

### 2.4 | Treatment

#### 2.4.1 | Child-centred play therapy intervention

The EXP group received the CCPT intervention between pre- and post-intervention assessment sessions, comprising eight individual 45-min sessions. The WL group did not receive CCPT in the same period but had the option to participate afterwards. The first author, a registered psychologist with extensive experience in CCPT and ASD, also a clinical supervisor in play therapy, monitored the intervention, administered by a trained certified play therapist in CCPT. The therapy was located in a classroom with utmost privacy and minimal interference from university students and staff members.



**FIGURE 1** Participant Flow through the Study. EEG: Electroencephalography; CCPT: Child-centred play therapy.

## 2.5 | Assessments/outcomes

Both the EXP and WL groups' children underwent the same EEG tests. Concurrently, parents filled out three behavioural assessment sets and a sociodemographic survey. The measurement sessions took place at The University of Hong Kong's Reading and Learning lab; the play therapy was conducted in a different building. Each session of EEG and behavioural assessments lasted about 1.5 h. Prior to gathering data, written consent from parents and assent from the children were collected. Once the children were acquainted with the EEG process and were prepared, the EEG tests were carried out.

## 2.6 | EEG measurements

### 2.6.1 | EEG recording and preprocessing

EEG recordings were taken in a dim, soundproof room. Children were instructed to stay calm, with minor movement allowed during sand-playing. After preparing the child with a 24-electrode cap, EEG signals were recorded using the mBraintrain SMARTING EEG amplifier with a sampling rate of 250 Hz, with electrodes placed according to the international 10–20 system. The data were online referenced to an electrode located between Cz and FCz.

For offline processing, data were filtered between 2 and 45 Hz to exclude noise. A 2 Hz high cut-off helped eliminate ocular artefacts

while retaining the alpha power band. Following band-pass filtering, problematic electrodes were identified and interpolated by calculating the standard deviation (SD) of each, with those exceeding four median absolute deviations (MADs) considered outliers. The MAD was calculated using the formula \

$$\text{MAD} = \text{median}(|A_i - \text{median}[A]|),$$

where  $A$  is a set of continuous values and  $A_i$  is each value. Finally, these data were re-referenced to the average. This method of re-referencing has been commonly used in EEG analysis (Luck, 2014).

### 2.6.2 | Designing activities and conditions

To gain a comprehensive understanding of the changes in children's neural responses in different social contexts, children were engaged in two 30-min EEG sessions: story-listening and sand-playing. Story-listening represents a common social situation in which another's presence is noted without direct interaction (Verbeke et al., 2014; Zajonc, 1965). Conversely, sand-playing represents an environment requiring children's active attention (Freeth et al., 2013). Each activity was divided into five blocks, containing three conditions: presence of a parent, a stranger or alone. The order of conditions was counterbalanced across participants to control for order effects. Each condition lasted 2 min, totalling 6 min per block (Figure 2).

**TABLE 1** Baseline sociodemographic and clinical characteristics of children and parents by group.

|                                   | EXP ( <i>n</i> = 34) | WL ( <i>n</i> = 31) |
|-----------------------------------|----------------------|---------------------|
|                                   | M (SD)               |                     |
| Age                               | 7.50 (1.19)          | 7.47 (1.37)         |
| AQ-Child                          | 91.12 (10.95)        | 87.29 (7.74)        |
| <i>Number of participants (%)</i> |                      |                     |
| <i>Gender</i>                     |                      |                     |
| Male                              | 27 (79%)             | 25 (81%)            |
| Female                            | 7 (21%)              | 6 (19%)             |
| <i>Place of birth</i>             |                      |                     |
| Hong Kong                         | 30 (88%)             | 29 (94%)            |
| Mainland China                    | 4 (12%)              | 2 (6%)              |
| <i>Handedness</i>                 |                      |                     |
| Right                             | 30 (88%)             | 29 (94%)            |
| Left                              | 4 (12%)              | 2 (6%)              |
| <i>Monthly income (HK\$)</i>      |                      |                     |
| <10k                              | 2 (6%)               | 1 (3%)              |
| 10–30k                            | 3 (9%)               | 0 (0%)              |
| 30–50k                            | 24 (70%)             | 27 (87%)            |
| >50k                              | 5 (15%)              | 3 (10%)             |
| <i>Parent education</i>           |                      |                     |
| Primary school                    | 1 (3%)               | 1 (3%)              |
| Secondary school                  | 2 (6%)               | 1 (3%)              |
| Associate                         | 13 (38%)             | 5 (16%)             |
| Undergraduate                     | 15 (44%)             | 20 (65%)            |
| Postgraduate                      | 3 (9%)               | 4 (13%)             |

Note: Means and standard deviations (in brackets) of participant's age and AQ-Child are shown; all other variables are presented as number of persons and percentages (in brackets).

Abbreviation: AQ-Child, Autism Spectrum Quotient—Child version.

### Sand-playing

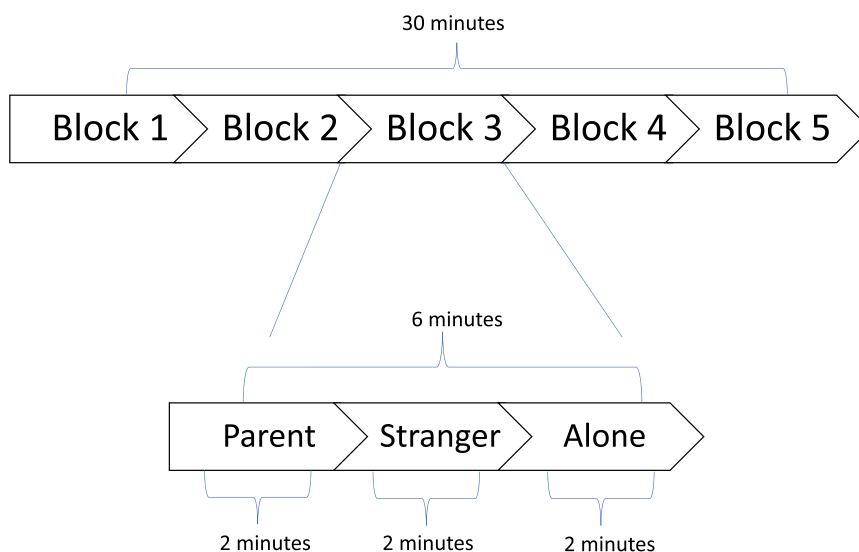
Children were instructed to play quietly with sand. The 'parent' condition involved the presence of a parent in the room, who entered and exited quietly without disturbing the child's behaviour. The 'stranger' condition followed the same process but with a laboratory staff member, who was blind to which group the participants belonged to, instead of the parent. In the 'alone' condition, children played solo. These conditions aimed to simulate presence without direct interaction.

### Story-listening

Children silently listened to a story under the same three conditions as the sand-playing. During the parent and stranger conditions, a parent or staff member read a story in a steady tone to maintain consistency. For the alone condition, a pre-recorded video of a staff member reading the story was used, simulating a situation without live interaction. The staff members were blind to which group the participants belonged to. The conditions simulated situations in which the child needed to pay attention to and look at either a parent, stranger or the video while listening to a story.

## 2.6.3 | Calculation of EEG frequency spectrum

After preprocessing, the EEG spectrum was computed using Bartlett's method. Data were divided into 1-s segments, and Fourier transform was applied using Matlab's 'fft' function. The frequency spectrum calculation for each segment yielded information about power at various frequencies. Averaging frequency spectra across all segments, electrodes, conditions and participants produced a representative spectrum for each condition. The alpha band (8–13 Hz) amplitude was specifically computed for each condition in accordance with the main assumption about the alpha's functional association, as described in the introduction.

**FIGURE 2** The experiment procedure. The sequence of parent–stranger–alone was randomised and counterbalanced across child participants.

## 2.7 | Behavioural measurements

### 2.7.1 | Social responsiveness scale, second edition (SRS-2)

SRS-2 assesses social impairment severity in autistic children aged 4–18 years. A higher total score indicates more severe social challenges. It has been extensively used in both clinical and research settings to assess the severity of social deficits (Constantino & Gruber, 2012). The SRS-2 has been validated in comparison with the standard diagnostic tools for ASD, including the Autism Diagnostic Observation Schedule (ADOS) (Charman et al., 2007; Constantino et al., 2007) and the Autism Diagnostic Interview-Revised (ADI-R) (Charman et al., 2007). The scale was reported to have good test-retest reliability and excellent internal consistency ( $\alpha = .97$ ; Constantino & Gruber, 2012). It has also been suggested to be highly sensitive to social functioning in autistic children (Van Hecke et al., 2015). In this study, the total raw score from the Chinese version of SRS-2 was used.

### 2.7.2 | Autism Spectrum Quotient—Children's version (AQ-Child)

The AQ-Child is a parent-reported measure that examines autism traits in children aged 4–11 years. It includes subscales that measure different dimensions of autism, with the social skill subscale being particularly relevant for our study. This subscale provides a focussed assessment of social functioning. Higher scores indicate more severe traits. The scale's internal consistency ( $\alpha = .91$ ) and test-retest reliability ( $r = .85$ ,  $p < .001$ ) have been reported to be significantly high for the child sample (Auyeung et al., 2008). In this study, the social skills subscale from the Chinese version of AQ-Child (Chan et al., 2008) was used.

### 2.7.3 | Adaptive Behaviour Assessment System-Second Edition (ABAS-II)

The ABAS-II is used to measure a child's adaptive behaviour related to personal and social skills for daily living. The social domain of the ABAS-II, which includes measures of leisure and social skills, was specifically chosen for our study due to its relevance in evaluating improvements in social interactions and adaptive behaviours. The scale boasts good internal reliability and exceptional internal consistency (Oakland & Harrison, 2011). In this study, the social domain (Leisure and Social) from the Chinese version of ABAS-II, Parent Form, was used.

## 2.8 | Statistical analysis

All variables were presented as means and standard deviations in this study. The spectrum and amplitude of the alpha band were calculated for different groups (EXP and WL), time points (pre- and

post-intervention assessment session), activities (story-listening and sand-playing) and conditions (parent, stranger and alone).

Before applying these tests, we conducted preliminary checks on the data distribution. Visual inspections of histograms and Q-Q plots, along with the Shapiro-Wilk test for normality, indicated that our data met the necessary assumptions for normal distribution. These assessments supported the appropriateness of using parametric tests for our analysis. Thus, a paired *t*-test was utilised to assess the significance of the difference in alpha band amplitude between pre- and post-intervention assessment sessions, as alpha amplitude was collected from the same participant across sessions. Independent sample *t*-test was utilised to assess the significance of the difference between different groups. The O<sub>2</sub> electrode, which shows the strongest alpha power, was chosen for the alpha power calculation, operationalised as the average amplitude between 8 and 12 Hz. The same statistical test was applied to assess differences in behavioural measurements, the SRS-2, AQ-Child (social skill subscale) and ABAS-II (social domain), between sessions.

Pearson's correlation coefficient was used to gauge the association between changes in alpha power and behavioural measurements. The correlation was calculated separately from all individual electrodes to show its distribution on the scalp.

## 3 | RESULTS

This study investigated the effects of CCPT on autistic children by employing EEG alpha power as a neural marker and questionnaires as behavioural markers. The research hypothesised that after CCPT, alpha power will be decreased because it is associated with mental relaxation. Besides, the CCPT would also show positive effects on the behavioural data as measured by SRS-2, the AQ-Child (social skill subscale) and the ABAS-II (social domain). We further hypothesised that the reduction in alpha power will be correlated with the improvement shown in the questionnaire scores. More specifically, the alpha power change after the CCPT is expected to be negatively correlated with the score changes in SRS-2 and AQ-Child's 'social skill' subscale, and positively correlated with score changes in ABAS-II social domain. These hypotheses were substantiated based on the observed correlations between alpha power measurements and the results derived from the standardised questionnaires, SRS-2, AQ-Child (social skill subscale) and ABAS-II (social domain).

### 3.1 | Increase in EEG alpha power after CCPT intervention

A paired-sample *t*-test was employed to investigate the variation in EEG alpha amplitude between the initial pre-intervention assessment and subsequent post-intervention assessment sessions across various social activities and conditions. Notably, the EXP group

exhibited a statistically significant increase in EEG alpha amplitude subsequent to the intervention ( $p < .001$ ) across all social activities and conditions (Table 2). In contrast, the WL group displayed a significantly lower alpha amplitude in all social conditions during the post-intervention assessment session in the story-listening, and also descriptively lower alpha in the sand-playing (Table 3).

For between-group differences, an independent sample *t*-test was conducted to compare the scores for EXP and WL for both story-listening and sand-playing. For story-listening, in the parent condition, there was no significant difference in pre-intervention EEG alpha amplitude between the EXP and WL groups ( $p = .70$ ),

**TABLE 2** Descriptive statistics (means, standard deviations, *p*-value) of EEG alpha amplitude on electrode O<sub>2</sub> between pre- and post-intervention assessment sessions for three social conditions (parent, stranger and alone) during two social activities (story-listening and sand-playing) among 34 autistic children from the EXP group.

|          | Story-listening | <i>p</i> | Sand-playing | <i>p</i> |
|----------|-----------------|----------|--------------|----------|
| Parent   |                 |          |              |          |
| Pre      | 2.80 (0.75)     | <.001    | 2.63 (0.73)  | <.01     |
| Post     | 3.65 (0.72)     |          | 3.57 (0.81)  |          |
| Stranger |                 |          |              |          |
| Pre      | 2.83 (0.92)     | <.001    | 2.52 (0.72)  | <.01     |
| Post     | 3.65 (0.75)     |          | 3.58 (0.89)  |          |
| Alone    |                 |          |              |          |
| Pre      | 2.92 (0.89)     | <.001    | 2.61 (0.70)  | <.01     |
| Post     | 3.85 (1.04)     |          | 3.63 (0.87)  |          |

Note: Means and standard deviations (in brackets) are shown. The *p*-values are for paired-samples *t*-tests comparing pre- and post-intervention scores.

**TABLE 3** Descriptive statistics (means, standard deviations, *p*-value) of EEG alpha amplitude on electrode O<sub>2</sub> between pre- and post-intervention assessment sessions for three social conditions (parent, stranger and alone) during two social activities (story-listening and sand-playing) among 34 autistic children from the WL group.

|          | Story-listening | <i>p</i> | Sand-playing | <i>p</i> |
|----------|-----------------|----------|--------------|----------|
| Parent   |                 |          |              |          |
| Pre      | 2.86 (0.51)     | <.001    | 2.54 (0.44)  | .05      |
| Post     | 2.41 (0.83)     |          | 2.23 (0.83)  |          |
| Stranger |                 |          |              |          |
| Pre      | 2.85 (0.57)     | <.001    | 2.54 (0.47)  | .05      |
| Post     | 2.36 (0.82)     |          | 2.21 (0.88)  |          |
| Alone    |                 |          |              |          |
| Pre      | 2.92 (0.62)     | <.001    | 2.56 (0.46)  | .06      |
| Post     | 2.42 (0.81)     |          | 2.24 (0.86)  |          |

Note: Means and standard deviations (in brackets) are shown. The *p*-values are for paired-samples *t*-tests comparing pre- and post-intervention scores.

while the post-intervention comparison showed a significant difference ( $p < .001$ ). In the stranger condition, no significant difference was found in the pre-intervention comparison ( $p = .92$ ), but a significant difference was observed post-intervention ( $p < .001$ ). Similarly, in the alone condition, the pre-intervention comparison showed no significant difference ( $p = .99$ ), while the post-intervention comparison revealed a significant difference ( $p < .001$ ). For sand-playing, in the parent condition, there was no significant difference in pre-intervention EEG alpha amplitude between the EXP and WL groups ( $p = .50$ ), while the post-intervention comparison showed a significant difference ( $p < .001$ ). In the stranger condition, no significant difference was found in the pre-intervention comparison ( $p = .90$ ), but a significant difference was observed post-intervention ( $p < .001$ ). Similarly, in the alone condition, the pre-intervention comparison showed no significant difference ( $p = .76$ ), while the post-intervention comparison revealed a significant difference ( $p < .001$ ). The effect sizes for both within-group and between-group comparisons are presented in Table 4.

The frequency spectra of the EEG signal were calculated to examine the variation in neural activity pattern in the three social conditions (parent, stranger and alone) during two activities (story-listening and sand-playing). The graphs illustrating the overall amplitude of electrode O<sub>2</sub> between the pre- and post-intervention assessment sessions are presented for the EXP group (Figure 3) and WL group (Figure 4), together with the scalp maps showing the distribution of the alpha power change.

For the EXP group, it is evident that the alpha band power (8–12 Hz, shaded area in Figure 3) exhibited higher values during the post-intervention assessment session as compared to the pre-intervention assessment session across all social activities and conditions. The increase in alpha band power was consistent across activities, that is, in both the story-listening and the sand-playing. The statistical analysis conducted through paired sample *t*-tests provides further support for these findings, revealing a significant enhancement in the alpha band power across all social activities and conditions following the CCPT intervention (Table 2).

The top-right corners of the plots in Figure 3 display the topographies of the difference (*t*-values) in alpha band power between the pre- and post-intervention assessment sessions (Figure 3). These difference maps distinctly illustrate a posterior distribution of the alpha band effect, which is consistent with the commonly found pattern of alpha power in the literature.

Contrary to the patterns observed in the EXP group, the WL group showed no increase in the alpha power. Specifically, the graphs revealed that the alpha band power (8–12 Hz, shaded area in Figure 4) exhibited descriptively higher values during the pre-intervention assessment session as compared to the post-intervention assessment session across all social activities and conditions. This difference was more pronounced during the story-listening than during the sand-playing. The statistical analysis based on paired sample *t*-tests confirmed the significance of this observation; that is, there is a significant decrease in the alpha band power during the post-intervention assessment session for all social

| Group    | Story-listening        |                         |          | Sand-playing           |                         |          |
|----------|------------------------|-------------------------|----------|------------------------|-------------------------|----------|
|          | Within-group <i>ds</i> | Between-group <i>ds</i> |          | Within-group <i>ds</i> | Between-group <i>ds</i> |          |
|          |                        | Pre to post             | Pre Post |                        | Pre to post             | Pre Post |
| Parent   |                        |                         |          |                        |                         |          |
| EXP      | 0.842                  |                         | 1.594    | 0.918                  | 0.163                   | 1.632    |
| WL       | -0.560                 | -                       | -        | -0.360                 | -                       | -        |
| Stranger |                        |                         |          |                        |                         |          |
| EXP      | 0.672                  |                         | 1.649    | 0.909                  | 0.031                   | 1.546    |
| WL       | -0.621                 | -                       | -        | -0.360                 | -                       | -        |
| Alone    |                        |                         |          |                        |                         |          |
| EXP      | 0.617                  |                         | 1.520    | 0.945                  | 0.076                   | 1.608    |
| WL       | -0.604                 | -                       | -        | -0.357                 | -                       | -        |

Note: Positive *ds* indicate increases in scores over time and negative *ds* indicate decreases.

Abbreviations: EXP, experimental group; WL, waitlist group.

activities and conditions, except for the alone condition in the sand-playing (Table 3). Unlike the EXP group, the difference maps in the WL group did not exhibit a posterior distribution of the alpha band effect across all social activities and conditions.

### 3.2 | Change in behaviour measurements after CCPT

To assess the changes in the scores for the SRS-2, AQ-Child (social skills) and ABAS-II (social domain) between the pre- and post-intervention assessment sessions, paired sample *t*-tests were employed for both the EXP and WL groups (Table 5). The results revealed significant differences in the EXP group.

In the EXP group, a significant decrease was noted in both the SRS-2 scores ( $p=.05$ ) and AQ-Child (social skills) scores ( $p<.001$ ), indicating an improvement in these two scales. Additionally, a significant increase in ABAS-II (social domain) scores was observed ( $p=.02$ ), which also indicates an improvement. Conversely, the WL group did not exhibit significant differences in SRS-2 and AQ-Child (social skills) scores between the pre- and post-intervention assessment sessions, while ABAS-II (social domain) showed a significant decrease in scores in the post-intervention assessment session (Table 5). For clarity and visual representation, the scores of the pre- and post-intervention assessment sessions for both the EXP and WL groups are extracted and presented as a bar chart (Figure 5).

### 3.3 | Correlation between neural effects and behavioural effects

To address the main research hypothesis concerning the cross-participant association between changes in alpha power and alterations in behavioural measurements before and after CCPT, Pearson's correlation coefficient was calculated to evaluate the relationship

between the two variables. The correlation analysis was conducted separately for the EXP and WL groups, and the results are shown in Table 6.

#### 3.3.1 | Alpha power and SRS-2

The correlation between the change in alpha power and SRS-2 in the EXP group is shown in Table 6. In the story-listening, there were significant, strong, negative relationships found in the parent, stranger and alone conditions ( $r(34)=-.88, p<.001$ ;  $r(34)=-.81, p<.001$ ;  $r(34)=-.72, p<.001$ , respectively). The scatterplots confirm and visualise the associations between the change in alpha power and SRS-2 score (Figure 6a-c), and the spatial distribution of the correlation is shown in the topographies (Figure 6a-c).

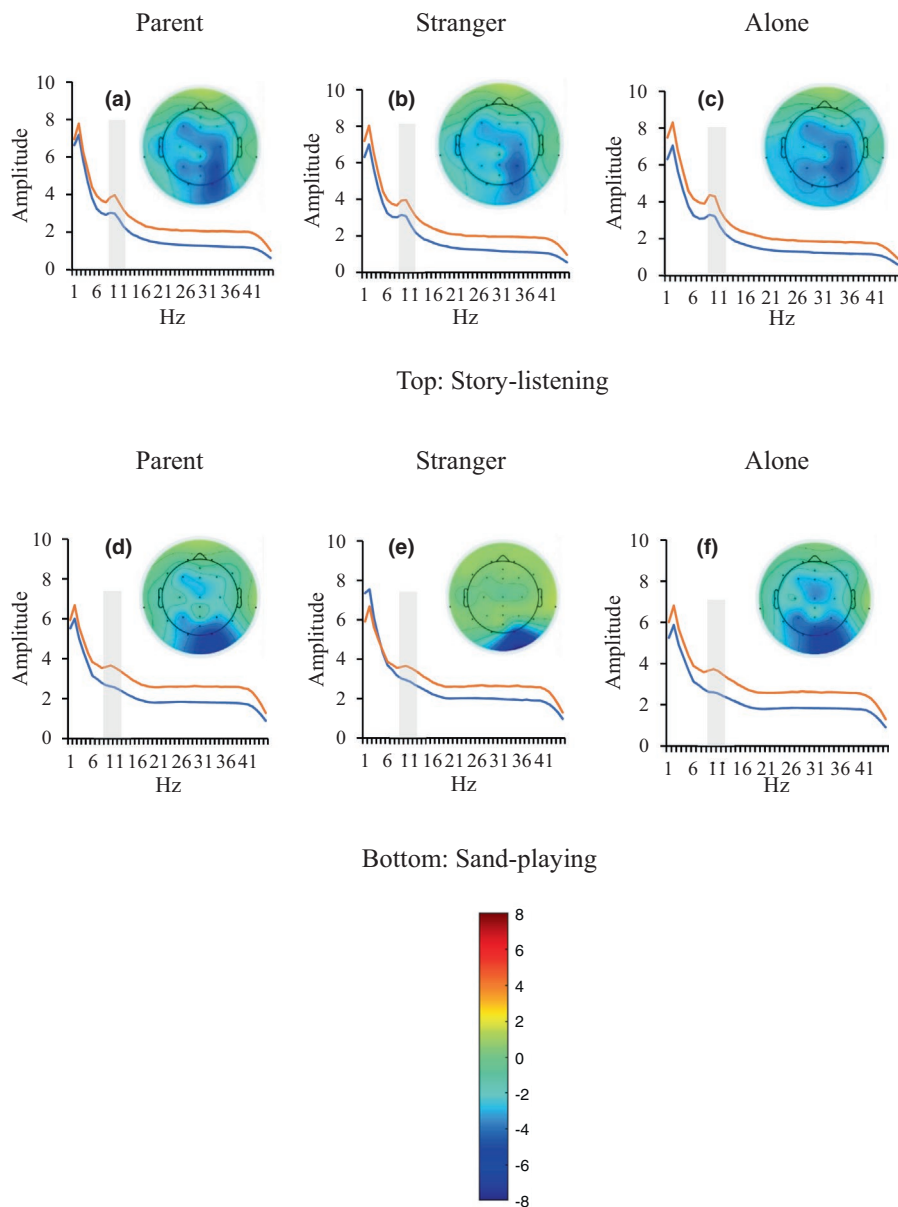
In the sand-playing for the EXP group, significant, moderate, negative relationships were found in the parent, stranger and alone conditions ( $r(34)=-.57, p<.001$ ;  $r(34)=-.52, p<.001$ ;  $r(34)=-.60, p<.001$ , respectively). The scatterplots confirm and visualise the associations between the change in alpha power and SRS-2 score (Figure 6d-f), and the spatial distribution of the correlation is shown in the topographies (Figure 6d-f).

For the WL group, the correlations between the change in alpha power and SRS-2 were not significant (Table 6), further confirmed by the scatterplots showing no association (Figure 6g-l).

#### 3.3.2 | Alpha power and AQ-Child (social skills)

The relationship between the change in alpha power and AQ-Child (social skills) in the EXP group is shown in Table 6. In the story-listening, significant, moderate, negative relationships were found between the change in alpha power and AQ-Child (social skills) in parent, stranger and alone conditions ( $r(34)=-.59, p<.001$ ;  $r(34)=-.41, p=.015$ ;  $r(34)=-.45, p<.001$ , respectively). Scatterplots confirm the

TABLE 4 Within-group and between-group effect sizes (Cohen's *d*) for EEG alpha amplitude on electrode O<sub>2</sub>.



**FIGURE 3** Difference in EEG spectrum between pre-intervention assessment (blue line) and post-intervention assessment (orange line) sessions for EXP group. The top panels (a-c) display the story-listening, and bottom panels (d-f) show the sand-playing, arranged in the order of parent, stranger and alone. Topographies of *t*-values resulting from the comparison between pre- and post-intervention assessment sessions across different social activities and conditions for the EXP group are also shown in the top-right corner of each plot. Each map is oriented as if looking down on the head, with frontal sites pointing towards the top of the page. Hz, Hertz.

associations between the change in alpha power and AQ-Child (social skills) score. The correlation shows topography patterns with a posterior distribution resembling typical alpha band power distribution (Figure 7a-c).

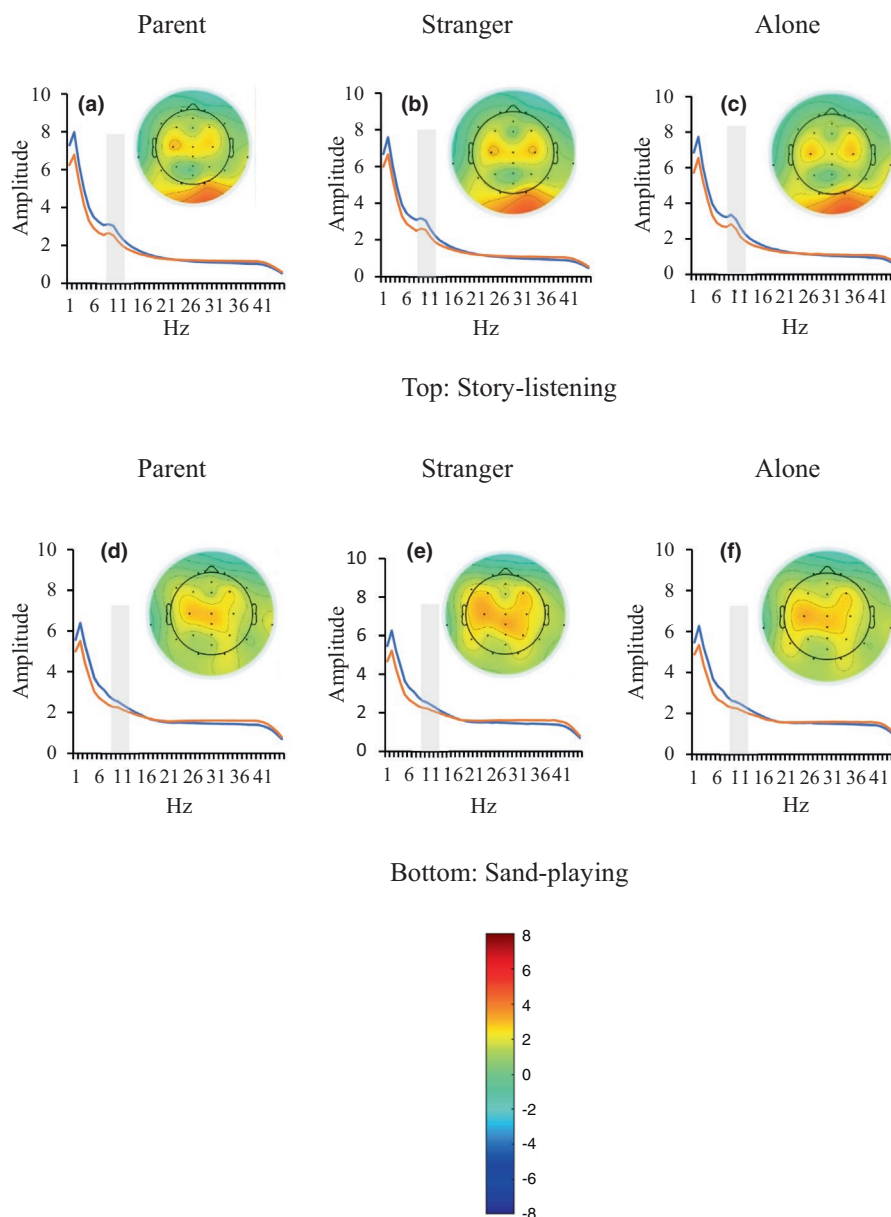
In the sand-playing for the EXP group, there was a significant, weak, negative relationship between change in alpha power and AQ-Child (social skills) in the parent condition ( $r(34) = -.36, p = .007$ ), but not in the stranger and alone conditions. Scatterplots confirm such a relationship (Figure 7d-f).

For the WL group, the relationships between the change in alpha power during all social activities and conditions and change in AQ-Child (social skills) were not significant (Table 6), with

scatterplots showing no association and topographies not displaying the typical posterior distribution of the alpha band power (Figure 7g-i).

### 3.3.3 | Alpha power and ABAS-II (social domain)

The relationship between the change in alpha power and ABAS-II (social domain) in the EXP group is shown in Table 6. In the story-listening, significant, moderate, positive relationships were found in the parent, stranger and alone conditions ( $r(34) = .44, p = .009$ ;  $r(34) = .51, p = .002$ ;  $r(34) = .52, p = .002$ , respectively). The scatterplots confirm



**FIGURE 4** Difference in EEG spectrum between pre-intervention assessment (blue line) and post-intervention assessment (orange line) sessions for WL group. The top panels (a-c) display the story-listening, and bottom panels (d-f) show the sand-playing, arranged in the order of parent, stranger and alone. Topographies of  $t$ -values resulting from the comparison between pre- and post-intervention assessment sessions across different social activities and conditions for the WL group are also shown in the top-right corner of each plot. Each map is oriented as if looking down on the head, with frontal sites pointing towards the top of the page. Hz, Hertz.

and visualise the associations between the change in alpha power and ABAS-II (social domain) score (Figure 8a-c), and the spatial distribution of the correlation is shown in the topographies (Figure 8a-c).

There were no significant relationships between the change in alpha power in the sand-playing and ABAS-II (social domain) (Table 6), which is further confirmed by the scatterplots showing no association (Figure 8d-f).

For the WL group, the correlations between the change in alpha power and ABAS-II (social domain) were not significant (Table 6), further confirmed by the scatterplots showing no association (Figure 8g-l).

## 4 | DISCUSSION

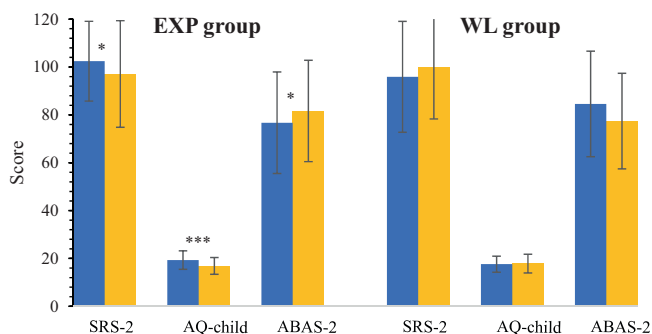
The present research provides a comprehensive examination of the effects of CCPT on neural and behavioural indicators and the relationship between variations in the two indicators across participants. As a neural indicator, the alpha power was adopted based on its association with relevant mental states. For behavioural indicators, three questionnaires were used to collect behavioural data related to characteristics in social skill domains. The main hypotheses were as follows: (1) CCPT would induce an improvement in the profiles indicated by both the neural and behavioural indicators; (2) the

**TABLE 5** Descriptive statistics of scores (mean, standard deviation, *p*-value and effect-size) on three sets of behavioural measurements between pre- and post-intervention assessment session for both the EXP and WL groups.

|                          | EXP            |          |                  | WL            |          |                  |
|--------------------------|----------------|----------|------------------|---------------|----------|------------------|
|                          | Mean (SD)      | <i>p</i> | Cohen's <i>d</i> | Mean (SD)     | <i>p</i> | Cohen's <i>d</i> |
| SRS-2                    |                |          |                  |               |          |                  |
| Pre                      | 102.44 (16.67) | .05      | −0.356           | 95.90 (23.18) | .09      | 0.319            |
| Post                     | 97.09 (22.28)  |          |                  | 99.74 (21.44) |          |                  |
| AQ-Child (social skills) |                |          |                  |               |          |                  |
| Pre                      | 19.32 (3.87)   | <.001    | −0.723           | 17.61 (3.35)  | .72      | 0.064            |
| Post                     | 16.88 (3.51)   |          |                  | 17.84 (3.91)  |          |                  |
| ABAS-II (social domain)  |                |          |                  |               |          |                  |
| Pre                      | 76.74 (21.21)  | .02      | 0.421            | 84.58 (22.07) | <.001    | −1.325           |
| Post                     | 81.65 (21.19)  |          |                  | 77.42 (19.96) |          |                  |

Note: Means and standard deviations (in brackets) of participants' scores. Positive *ds* indicate increases in scores over time and negative *ds* indicate decreases.

Abbreviations: ABAS-II, Adaptive Behaviour Assessment System-II; AQ-Child, Autism Spectrum Quotient—Child version; EXP, experimental group; SRS-2, Social Responsiveness Scale-2; WL, waitlist group.



**FIGURE 5** Graph representing mean and standard deviations of the scores for the EXP group and WL group on three measurements in the pre-intervention assessment session (blue bars) and post-intervention assessment session (orange bars). Significance was based on paired *t*-test, so the error bars (representing cross-participant variance) do not directly imply the significance level. SRS-2, Social Responsiveness Scale-2; AQ-Child, Autism Spectrum Quotient—Child version; ABAS-II, Adaptive Behaviour Assessment System-II. EXP, experimental group; WL, waitlist group. \*\*\*Correlation is significant at the .001 level (two-tailed). \*Correlation is significant at the .05 level (two-tailed).

changes in neural indicator should be correlated with the changes in the behavioural indicators; that is, participants who showed more improvement in the questionnaire data should also show larger increases in the alpha power that indicates a generic mental relaxation in a social context. The findings robustly supported these hypotheses on multiple levels.

The results showed that the EXP group displayed a significant increase in alpha power post-CCPT across different social activities and conditions, indicating a generalised effect of CCPT on the neural activity of autistic children. This finding substantiates the first part of our hypotheses, affirming the positive impact of CCPT on alpha power modulation in autistic children. In contrast, the WL group showed no alpha power increase. This distinction reinforces CCPT's

role in triggering changes in the alpha power, as the WL group, which did not receive the intervention, exhibited no such variations in alpha power.

Complementing the neural outcomes, significant behavioural improvements were also observed in the EXP group post-CCPT. The SRS-2 and AQ-Child (social skills) scores showed a decline, indicating less severe social impairments, while the ABAS-II (social domain) scores increased, also signalling positive progress in the social domain. The direction of these score changes aligns with the expected outcomes of CCPT, which indicated an improvement in social functioning and adaptive behaviours in autistic children. This behavioural enhancement is in accordance with our hypotheses, which expected a positive effect of CCPT on the behavioural measurements of autistic children. The WL group, on the contrary, demonstrated no significant differences in the questionnaire scores, further supporting the influence of CCPT on the behavioural improvements observed in the EXP group.

The most critical aspect of our hypotheses was the cross-participant correlation between changes in alpha power and alterations in behavioural measurements. The results substantiated this aspect as well, showing a strong correlation between the increase in alpha power and the improvement in behavioural measures in the EXP group. The increase in alpha power was negatively correlated with SRS-2 and AQ-Child scores (indicating the greater the alpha power increase, the greater the decrease in these scores, hence an improvement). The alpha power increase was positively correlated with ABAS-II scores (signifying the greater the alpha power increase, the greater the increase in these scores, hence an improvement). These correlations provide vital insights into the individual-level impacts of CCPT, as they elucidate how CCPT has a solid effect in both neural and behavioural aspects that validate each other through the clear individual differences. In other words, only genuine effect would lead to a result pattern that change in behaviour is bound to change in neural features. The strong correlation demonstrates the

|                 | EXP                 |                     |                    | WL     |          |         |
|-----------------|---------------------|---------------------|--------------------|--------|----------|---------|
|                 | SRS-2               | AQ-Child            | ABAS-II            | SRS-2  | AQ-Child | ABAS-II |
| Story-listening |                     |                     |                    |        |          |         |
| Parent          | -0.879 <sup>a</sup> | -0.590 <sup>a</sup> | 0.442 <sup>a</sup> | -0.002 | 0.073    | 0.186   |
| Stranger        | -0.814 <sup>a</sup> | -0.414 <sup>b</sup> | 0.507 <sup>a</sup> | -0.073 | 0.047    | 0.101   |
| Alone           | -0.721 <sup>a</sup> | -0.454 <sup>a</sup> | 0.520 <sup>a</sup> | -0.038 | 0.149    | 0.161   |
| Sand-playing    |                     |                     |                    |        |          |         |
| Parent          | -0.569 <sup>a</sup> | -0.285              | 0.258              | 0.009  | 0.206    | 0.218   |
| Stranger        | -0.515 <sup>a</sup> | -0.255              | 0.125              | 0.016  | 0.290    | 0.250   |
| Alone           | -0.603 <sup>a</sup> | -.363 <sup>b</sup>  | 0.167              | 0.018  | 0.256    | 0.234   |

Note: SRS-2, Social Responsiveness Scale-2; AQ-Child, Autism Spectrum Quotient—Child version; ABAS-II, Adaptive Behaviour Assessment System-II.

Abbreviations: EXP, experimental group; WL, waitlist group.

<sup>a</sup>Correlation is significant at the 0.01 level (2-tailed).

<sup>b</sup>Correlation is significant at the 0.05 level (2-tailed).

**TABLE 6** Correlations between the change of the alpha amplitude on electrode O<sub>2</sub> during different social activities and conditions and the change in behavioural outcomes following a CCPT intervention (EXP group) or waiting period (WL group).

potential of developing an individual-level indicator of CCPT effects. The absence of such correlations in the WL group further confirms the unique effect of CCPT that does not originate from the time effect.

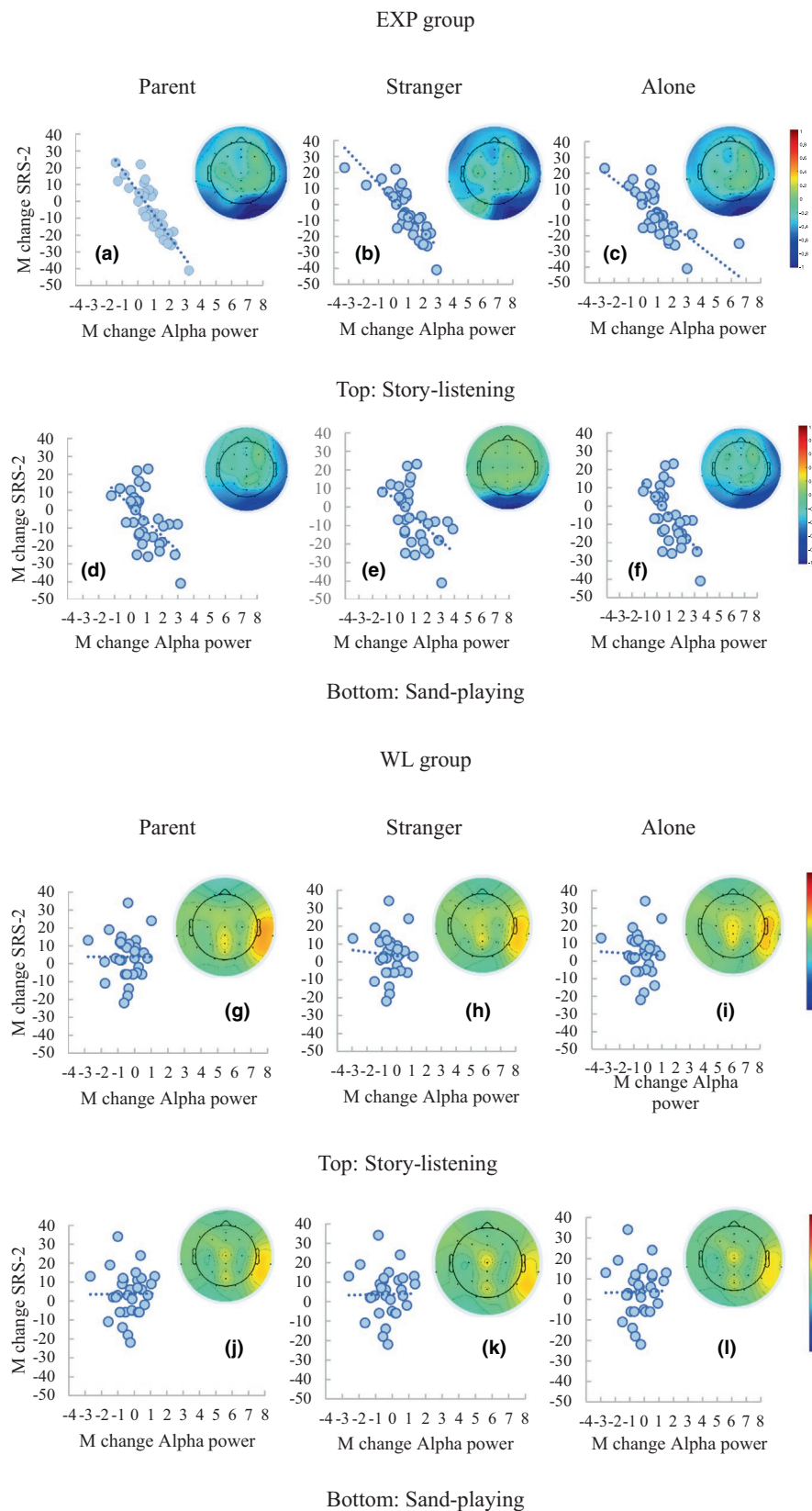
The increase in alpha power observed in the EXP group following CCPT can be interpreted according to the existing literature on the neurophysiological effects of therapeutic interventions. Prior research has extensively established that an increase in alpha power is indicative of a state of relaxation (Klimesch, 1999), which makes it a possible neurophysiological marker of post-therapy calming effects. In the context of therapy and its neurophysiological impacts, some studies have reported changes in brain rhythms, particularly in the alpha band, following various interventions (e.g. Thibault et al., 2016). This aligns with our findings, suggesting that CCPT can modulate neural activities, indexed by the alpha power, in autistic children. CCPT has been proposed to have a distinct effect driven by its child-focussed nature that offers the child a safe and accepting environment to freely express themselves (Landreth, 2012). This child-focussed approach is likely pivotal in fostering feelings of relaxation, which, in turn, could be driving the observed neurophysiological changes, particularly the increases in alpha power. This explanation can be further supported by research on mindfulness-based interventions that have shown effects in increasing alpha activity, suggesting a state of relaxed alertness (Jaiswal et al., 2019; Kerr et al., 2011; Keune et al., 2011). Because CCPT includes similar mechanisms with mindfulness training that guides the participant or practitioner to focus on the present moment and create a non-judgemental awareness, it could be expected that similar neural changes may be induced by the two programmes.

#### 4.1 | Implications for research and practice

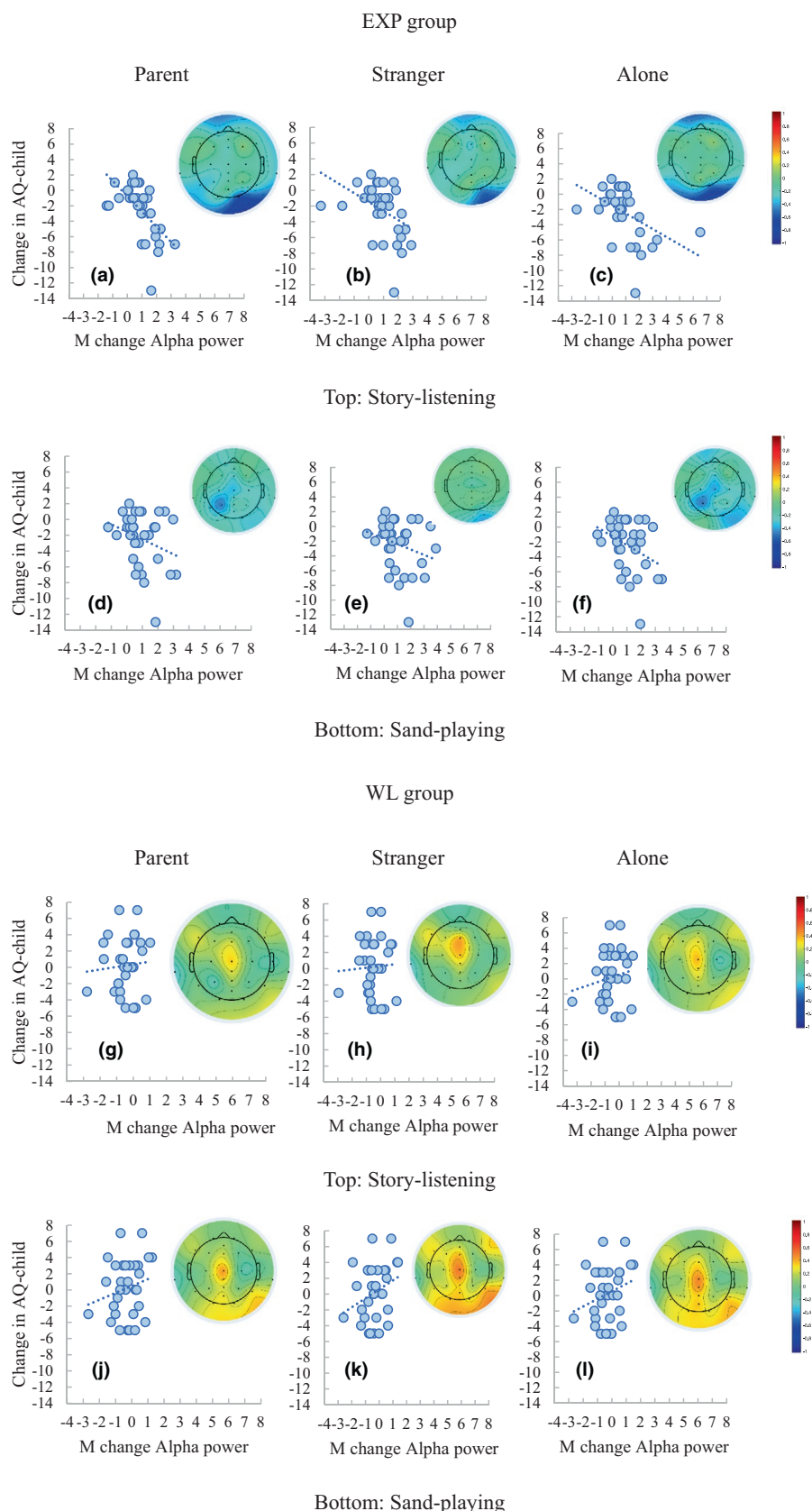
This is a pioneering study that evaluates the effect of CCPT at two levels: group effects and individual differences. The main novel

component in this study is the examination of the neural effects. The neural data offer a strong validation of the CCPT effect by providing evidence that the effect is not just manifested in the behavioural improvement, but also in the brain. The findings contribute to the existing body of knowledge in two critical ways. First, our research findings cross-validated the current and previous reports of CCPT effects reported by behavioural measurement by providing neural support, highlighting the multidimensional impacts of CCPT on autistic children. Most notably, our study revealed a significant correlation between the changes in alpha power and the changes in questionnaire scores. The correlation effectively ruled out the possibility that the CCPT effects are spurious findings (Bro et al., 2008). In other words, if the CCPT effect was only found in the behavioural data and if there was no correlation between the neural and behavioural measures, the improvement in the behavioural measures could be due to trivial factors such as familiarity with the testing and evaluation procedures. By demonstrating consistent and correlated changes in two different levels of measurement (i.e. neural and behavioural), our study strongly validates that the CCPT effects truly reached the neural and cognitive systems.

Second, the findings of this study offer substantial evidence of the utility and relevance of the selected measures in quantifying the impacts of CCPT at an individual level. Notably, the change in EEG alpha power and the alterations in questionnaire scores provide solid evidence of how each child responded differentially to CCPT, enabling a nuanced understanding of individual differences in therapeutic outcomes. Individual differences shown in the multilevel measurements are the foundation for further developing individualised therapy. Each child exhibited unique patterns of improvement in behavioural data, with some children showing more pronounced changes in certain aspects than others. This individual-level understanding is crucial for tailoring therapeutic strategies to better meet each child's needs and for tracking their progress more accurately (Norcross & Wampold, 2018). One example of potential utility of the individual specific data is that improvement in one level (either

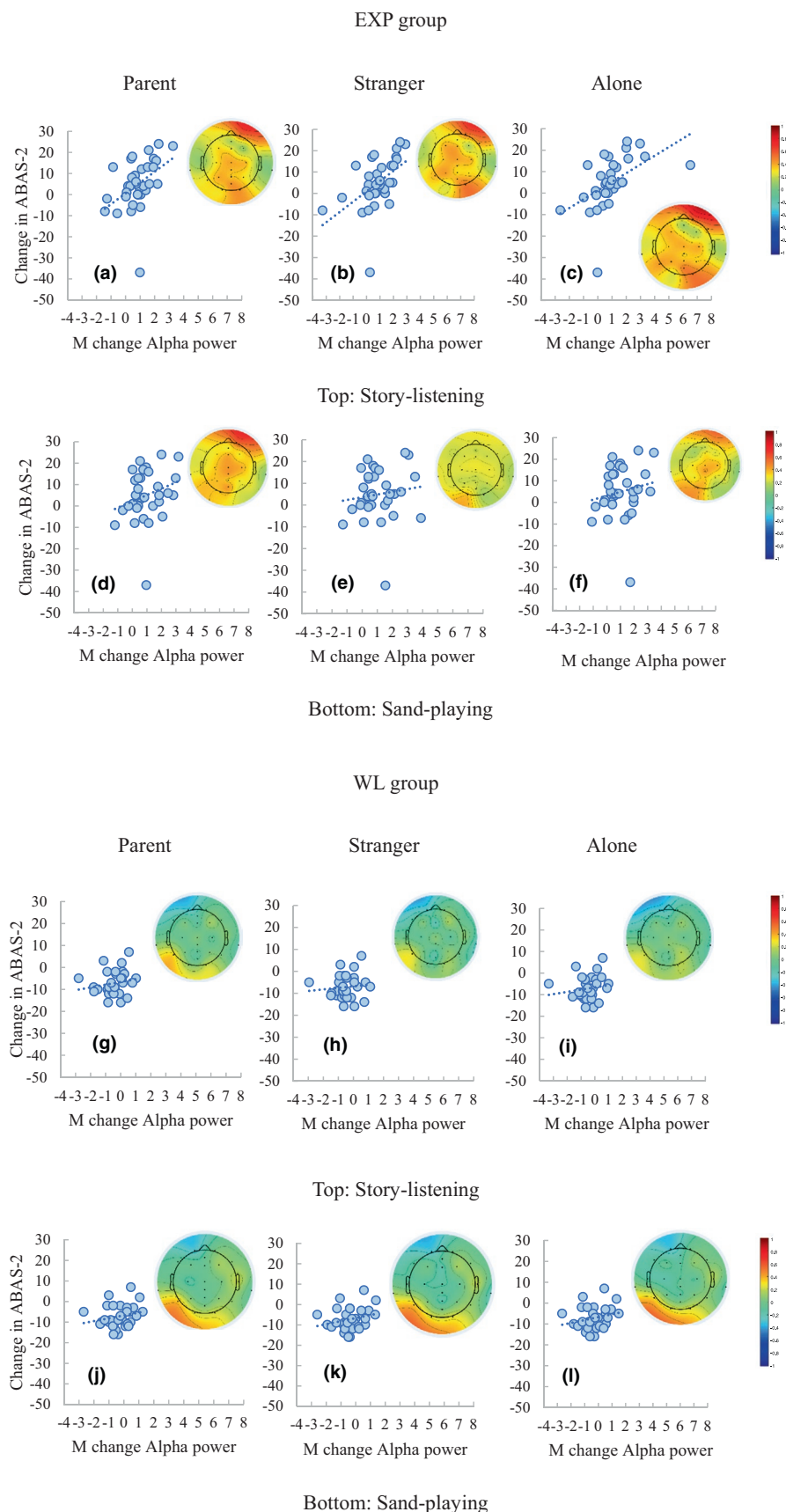


**FIGURE 6** Correlation maps depicting the relationship between changes in alpha amplitude on electrode O<sub>2</sub> and changes in SRS-2 scores between pre- and post-intervention assessment sessions for 34 children in the EXP group and 31 children in the WL group in different social activities. EXP group (a–f) and WL group (g–l) in different social activities (Top: story-listening; Bottom: sand-playing). The distributions of the correlation value on the scalp are displayed in the upper right corner of the scatterplots, with frontal sites oriented towards the top of the page. M, Mean. SRS-2, Social Responsiveness Scale-2.



**FIGURE 7** Correlation maps depicting the relationship between changes in alpha amplitude on electrode O<sub>2</sub> and changes in AQ-Child (social skills) scores between pre- and post-intervention assessment sessions for 34 children in the EXP group and 31 children in the WL group in different social activities. EXP group (a–f) and WL group (g–l) in different social activities (Top: story-listening; Bottom: sand-playing). The distributions of the correlation value on the scalp are displayed in the upper right corner of the scatterplots, with frontal sites oriented towards the top of the page. M, Mean. AQ-Child, Autism Spectrum Quotient – Child version.

**FIGURE 8** Correlation maps depicting the relationship between changes in alpha amplitude on electrode O<sub>2</sub> and changes in ABAS-II (social domain) scores between pre- and post-intervention assessment sessions for 34 children in the EXP group and 31 children in the WL group in different social activities. EXP group (a–f) and WL group (g–l) in different social activities (Top: story-listening; Bottom: sand-playing). The distributions of the correlation value on the scalp are displayed in the upper right corner of the scatterplots, with frontal sites oriented towards the top of the page. M, Mean. ABAS-II, Adaptive Behaviour Assessment System-II.



neural or behavioural) may not be sufficient for the therapist to confirm the effect of the therapy and make a decision on whether the training programme should be finished. Improvement in both neural

and behavioural measures would provide a much stronger evidence base for the therapist to make decisions. This approach is particularly advantageous as it takes into account the individual differences

that are a key characteristic of ASD (Lerner et al., 2022; Venker et al., 2013).

It is worth noting that there was a significant drop in EEG alpha amplitude measures and ABAS-II scores in the WL group during the post-intervention assessment session. The decrease in ABAS-II (social domain) scores indicates fewer social interactions and less adaptive behaviours, which is consistent with the reduction in alpha power, typically associated with decreased relaxation (Klimesch, 1999). One possible explanation is that the children experienced increased stress about the experiment after undergoing the first assessment, as they knew they were expected to remain quiet and follow instructions for more than an hour. The lower ABAS-II scores do not conflict with the decrease in alpha power or our research conclusions. While we cannot currently provide a definitive explanation for the drop in ABAS-II scores, this observation does not contradict the focus of our current research. Future studies should aim to investigate this phenomenon further to better understand the underlying reasons for these changes.

The differences between pre- and post-EEG alpha amplitude for story-listening were generally larger than those for sand-playing. This suggests that story-listening may be more effective in engaging neural mechanisms related to relaxation and reduced cognitive workload. The existing literature indicates that activities requiring sustained attention and auditory processing, such as story-listening, may be more effective in eliciting neural changes compared to more interactive and less structured activities, such as sand-playing (Klimesch, 1999).

## 4.2 | Limitations

While the current study provides valuable insights, there still exist some limitations in the present study. According to the existing literature about the functional roles of alpha oscillation, higher alpha power is often associated with states of relaxation, reduced anxiety and enhanced cognitive performance (Klimesch, 1999). Therefore, given the role of CCPT in alleviating anxiety and improving social skills in autistic children, we reasoned that the alpha power would provide a suitable neural index of these changes. While the hypothesis about alpha is confirmed in this study, it is also noted that the CCPT effects on the EEG spectrum appears to cover the broadband, not just in the alpha oscillation, although the alpha band appeared to be stronger than other bands in reflecting the effect. There may be additional neural mechanisms beyond the alpha-related ones that are implicated in the CCPT effect, which may potentially broaden our understanding of the neurophysiological implications of the therapy if the full spectrum and detailed dynamics are more thoroughly studied (Buzsaki & Draguhn, 2004). Furthermore, behavioural outcomes in this study were based exclusively on parental reports, which may introduce bias, particularly if parents were aware of their child's group assignment (experimental or waitlist). This bias could potentially affect the observed differences between the EXP and WL scores.

Future studies should consider incorporating a more comprehensive analysis of various brainwaves to capture a fuller picture of the neurophysiological changes following CCPT. Examining the variations in different frequency bands, the interplay between them, and how they are related to behavioural improvements, might yield a more nuanced understanding of how CCPT benefits autistic children.

## 5 | CONCLUSION

This study has provided significant evidence that supports a multi-level effect of CCPT on autistic children on both neural and behavioural levels and suggests this significant correlation between the neural and behavioural effects further provides a cross-validation of the impact of CCPT. The identified correlations between changes in alpha power and behavioural scores also implies a potential of developing individualised CCPT interventions in future development of therapeutic strategies.

## ACKNOWLEDGEMENTS

This work was supported by the Hong Kong Research Grant Council (17609321) and the Seed Fund for Basic Research from the University of Hong Kong (2203100569, 2202100568) to G.O.

## CONFLICT OF INTEREST STATEMENT

We have no known conflict of interest to declare.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author, G.O., upon reasonable request.

## ETHICS STATEMENT

All procedures performed in studies involving human participants were in accordance with the ethical standards of the Human Research Ethics Committee at the University of Hong Kong and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Human Research Ethics Committee (EA210015) at the University of Hong Kong.

## CONSENT

Informed consent was obtained from all individual adult participants included in the study; assent was obtained from children.

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**How to cite this article:** Chan, K.-L.R., & Ouyang, G. (2025). Association between changes in EEG alpha power and behavioural outcome in autistic children induced by child-centred play therapy: A randomised controlled trial. *Counselling and Psychotherapy Research*, 25, e12813. <https://doi.org/10.1002/capr.12813>