BRAIN ACTIVITY AND CHANGES IN DEPRESSIVE SYMPTOMS FOLLOWING COGNITIVE RESTRUCTURING IN DEPRESSIVE DISORDERS: A CASE SERIES

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by

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DECLARATION

I hereby declare that the research work entitled “Brain Activity and Changes in Depressive Symptoms Following Cognitive Restructuring in Depressive Disorders: A Case Series” is a record of original work of my own; and to the best of my knowledge, it does not contain materials that is being published in the past or written by others except where resources are properly acknowledged in the text; and that it has not been submitted in part or in whole to any other University or Institute for the purpose of publications. In making this declaration, I wholly understand the presence of any breaches off the declaration constitute academic misconduct may lead to certain penalties.

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Student’s Signature Date

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LIST OF SYMBOLS

kΩ	Kilo-ohms, which is a unit of electrical resistance
μV^2	Microvolts squared

LIST OF ABBREVIATIONS

AIDS	Acquired Immunodeficiency Syndrome
ATQ	Automatic Thoughts Questionnaire
BA	Behavioural activation
BAI	Beck Anxiety Inventory
BDI	Beck Depression Inventory
CAN-BIND	Canadian Biomarker Integration Network in Depression
CBT	Cognitive behavioural therapy
CR	Cognitive restructuring
DLPFC	Dorsolateral prefrontal cortex
DMTS	Delayed matching to sample
DSM-5-TR	Diagnostic and Statistical Manual of Mental Disorders 5th Version Text Revised
EEG	Electroencephalography
EOG	Electrooculography
FAA	Frontal Alpha Asymmetry
fMRI	functional magnetic resonance imaging
HDRS	Hamilton Depression Rating Scale
HIV	Human Immunodeficiency Virus
HPUSM	Hospital Pakar Universiti Sains Malaysia
Hz	Hertz
ICA	Independent Component Analysis
IR	Imagery rescripting
LRTC	Long-range temporal correlations
MCCB	MATRICS Consensus Cognitive Battery
MDD	Major Depressive Disorder
NIMH	National Institute of Mental Health
PET	positron emission tomography
PHQ	Patient Health Questionnaire
PLV	Phase locking values
rs-EEG	Resting-state EEG
SPSS	Statistical Package for Social Sciences
VR	Virtual reality

LIST OF APPENDICES

AKTIVITI OTAK DAN PERUBAHAN GEJALA KEMURUNGAN SELEPAS PENSTRUKTURAN KOGNITIF DALAM KALANGAN INDIVIDU DENGAN GANGGUAN KEMURUNGAN: SIRI KES

ABSTRAK

Kemurungan merupakan masalah kesihatan mental utama dengan asas psikologi dan neurobiologi. Penstrukturan kognitif (CR), komponen teras dalam Terapi Tingkah Laku Kognitif (CBT), berkesan mengurangkan pemikiran automatik negatif dan simptom kemurungan, namun sedikit kajian meneliti kesannya terhadap aktiviti otak menggunakan elektroensefalografi (EEG), khususnya di Malaysia. Kajian siri kes ini meneliti hasil klinikal dan neurofisiologi intervensi CR berstruktur dalam kalangan individu dengan gangguan kemurungan.

Tiga peserta wanita berumur 20-23 tahun dengan diagnosis *Major Depressive Disorder* (seorang juga dengan *Persistent Depressive Disorder*) menjalani enam sesi CR individu. EEG keadaan rehat (mata tertutup, mata terbuka) direkod sebelum dan selepas intervensi, memfokuskan kepada kuasa mutlak *alpha* (8–13 Hz) dan *theta* (4–7 Hz) di elektrod F3, kawasan yang berkaitan dengan regulasi emosi. Ukuran klinikal termasuk versi Bahasa Melayu *Beck Depression Inventory* (BDI), *Beck Anxiety Inventory* (BAI) dan *Automatic Thoughts Questionnaire* (ATQ).

Semua peserta menunjukkan peningkatan klinikal bermakna. Peserta 1: BDI 34 ke 20, BAI 27 ke 23, ATQ (item 4–5) 14 ke 8. Peserta 2: BDI 32 ke 19, BAI 10 ke 4, ATQ 18 ke 1. Peserta 3: BDI 20 ke 3, BAI 21 ke 0, ATQ 5 ke 0. EEG menunjukkan perubahan khusus mengikut peserta: Peserta 1 sedikit meningkat dalam kedua-dua jalur; Peserta 2 menurun *alpha* (MT) tetapi meningkat *alpha* (MB) dan *theta* secara ketara; Peserta 3 meningkat besar *alpha* dan *theta*, terutama *theta* (MT: 0.04 ke 42.09 μV^2).

Dapatan mencadangkan CR berpotensi mengurangkan simptom kemurungan dan pemikiran negatif sambil menghasilkan perubahan EEG keadaan rehat, khususnya dalam jalur *alpha* dan *theta*. EEG berpotensi memantau respons neural individu terhadap psikoterapi dan menyokong penggunaannya dalam amalan klinikal serta penjagaan kesihatan mental yang relevan dengan budaya di Malaysia.

Kata kunci: penstrukturan kognitif, terapi tingkah laku kognitif, kemurungan, elektroensefalografi, osilasi otak

BRAIN ACTIVITY AND CHANGES IN DEPRESSIVE SYMPTOMS FOLLOWING COGNITIVE RESTRUCTURING IN DEPRESSIVE DISORDERS: A CASE SERIES

ABSTRACT

Depression is a major mental health concern with psychological and neurobiological underpinnings. Cognitive restructuring (CR), a core component of cognitive behavioural therapy (CBT), is effective in reducing negative automatic thoughts and depressive symptoms, yet few studies have examined its neural effects using electroencephalography (EEG), particularly in Malaysia. This case series explored clinical and neurophysiological outcomes of a structured CR intervention in individuals with depressive disorders.

Three female participants aged 20-23 years old with clinically diagnosed Major Depressive Disorder (one also with underlying Persistent Depressive Disorder) completed six individual CR sessions. Resting-state EEG (eyes closed, eyes open) was recorded pre- and post-intervention, focusing on absolute alpha (8–13 Hz) and theta (4–7 Hz) power at the F3 electrode, associated with emotional regulation. Clinical measures included the Malay versions of the Beck Depression Inventory (BDI), Beck Anxiety Inventory (BAI), and Automatic Thoughts Questionnaire (ATQ).

All participants showed clinically meaningful improvements. Participant 1: BDI 34 to 20, BAI 27 to 23, ATQ (items 4–5) 14 to 8. Participant 2: BDI 32 to 19, BAI 10 to 4, ATQ 18 to 1. Participant 3: BDI 20 to 3, BAI 21 to 0, ATQ 5 to 0. EEG results showed participant-specific changes: Participant 1 had modest increases in both bands;

Participant 2 showed reduced alpha (EC) but increased alpha (EO) and marked theta gains; Participant 3 had large alpha and theta increases, especially theta (EC: 0.04 to 42.09 μV^2).

Findings suggest CR may reduce depressive symptoms and negative thoughts while inducing measurable resting-state EEG changes, particularly in alpha and theta bands. EEG shows promise for monitoring individualised neural responses to psychotherapy, supporting integration into clinical practice and culturally relevant care in Malaysia.

Keywords: cognitive restructuring, cognitive behaviour therapy, depression, electroencephalography, oscillations

CHAPTER 1

GENERAL INTRODUCTION & LITERATURE REVIEW

1.1 General Introduction

Depression is projected to be the second leading cause of global disease burden after HIV/AIDS and has a significant rise in cases of 38.9% between the year 1990 and 2019 (GBD, 2022; Hock et al., 2012; Salleh, 2018). In Malaysia, the National Health and Morbidity Survey 2019 reported that depression cases amongst adults aged 16 years old and above saw an increase from 1.8% in 2011 to 2.3% in 2020. According to The Diagnostic and Statistical Manual of Mental Disorders 5th Version Text Revised (DSM-5-TR), depressive disorders are commonly characterised by the following symptoms: depressed mood, anhedonia, significant weight or appetite change, insomnia or hypersomnia, psychomotor agitation or retardation, fatigue, feeling of worthlessness or inappropriate guilt, decreased concentration, and thoughts of death and suicide (APA, 2022).

People with depressive disorders frequently experience symptoms of anxiety alongside core depressive features, and a recent systematic review show substantial comorbidity between mood and anxiety disorders – an overlap that complicates diagnosis, prognostic assessment, and treatment planning (Saha et al., 2020). Concurrently, cognitive models and cross-continental empirical work indicate that depressed individuals report a high frequency of automatic negative thoughts (self-critical, hopeless, or helpless self-statements), making negative automatic cognition a hallmark correlate of depressive symptomatology across cultures (Chahar Mahali et al., 2020). Evidence from recent clinical and population studies further shows that such automatic negative thoughts not only correlate with depression severity but can mediate links from stress or depression to downstream outcomes (including suicidal ideation and broader emotional/behavioural problems), which further emphasises their role as both a clinical marker and a mechanistic treatment target in clinical interventions for individuals with depression (Pedro et al., 2019; Shen et al., 2023).

As the incidence of depression increases, so does the need for effective treatment. In a review of validated treatments for depression published in 2021, Karrouri and colleagues divided them into three categories: pharmacotherapy, psychotherapy, and somatic treatments. In most cases, medication is used alongside psychotherapy to treat the symptoms of depression. The National Institute of Mental Health (NIMH) defines psychotherapy as a range of treatments that help identify and change troubling thoughts, emotions, and behaviours. One of the most scientifically supported psychotherapies is cognitive behavioural therapy (CBT). CBT was first developed by Aaron Beck in the 1960s and focuses on challenging one's irrational thoughts and beliefs that affected their moods and behaviours (NHS, 2021). Cognitive restructuring (CR) and behavioural activation (BA) are the most common techniques under CBT used to treat depression. A meta-analysis of 45 studies by Ciharova et al. (2021) reviewed all three components: CBT, CR and BA in their effectiveness in treating depression. They concluded that all three were found to be equally effective, with BA having a similar effectiveness as a full CBT. However, they do not have enough data to support CR alone.

With the emergence of innovative techniques to treat depression, brain imaging technologies have also been utilised to gain a better understanding of this specific disorder. Among the common neuroimaging techniques are functional magnetic resonance imaging (fMRI), positron emission tomography (PET), and electroencephalography (EEG) (Dunlop & Mayberg, 2017; Simmatis et al., 2023). Among these tools, EEG has been regarded to be an ideal tool to measure significant brain activities as it captures neuronal oscillations in milliseconds, non-invasive to patients, and accessible (Simmatis et al., 2023). Neuroimaging technologies are important not only to determine biomarkers of depression, but also to track progress of patients' treatment and studying the effectiveness of treatment approaches. Studies have found significant brain wave changes especially in alpha and theta wave, which may be of significance to explore in this study (Wang et al., 2022).

In particular, resting-state EEG studies have identified altered oscillatory patterns in individuals with depression, most consistently in the alpha and theta frequency bands. Reduced alpha power is often observed in frontal and parietal regions – potentially reflecting impaired cognitive and emotional regulation (de Aguiar Neto & Rosa, 2019; Umemoto et al., 2021; Xie et al., 2024; Zhang et al., 2020). Elevated theta activity, especially in the left parietal areas, has also been reported and is thought to reflect increased internal focus and rumination. For instance, Wang et al. (2022) documented heightened left-parietal theta in depressed samples during resting state, linking it to rumination, and a similar finding was confirmed in an independent study by Li et al. (2024). Additionally, Huang et al. (2023) observed significantly elevated theta power in right occipital regions among first-episode, drug-naïve patients with major depressive disorder, while Gradwohl et al. (2024) found increased frontal and occipital-parietal theta activity in adolescents with depression. These neurophysiological alterations at rest may serve as potential biomarkers for depressive symptomatology and provide insight into the effects of psychotherapy such as cognitive restructuring on brain function.

1.2 Depression and Cognitive Restructuring

Cognitive restructuring (CR) is a pivotal component of CBT aimed at identifying and altering dysfunctional thoughts and beliefs. Given the increasing prevalence of depression worldwide, understanding the efficacy and implementation of CR is crucial. Multiple studies affirm the efficacy of CR in reducing depressive symptoms as reflected in a meta-analysis study by Ciharova et al. (2021). They reviewed 45 studies that implemented CBT, BA, or CR, and the reported effectiveness. They concluded that CBT, CR, and BA are all equally effective in treating depression with BA having a similar effect as a full CBT. However, they noted insufficient data to support the standalone effectiveness of CR. This gap in evidence highlights the need for more focused research on CR's independent impact.

In 2019, Marasigan conducted an experimental research to compare the efficacy of CR and cognitive defusion techniques in coping with negative thoughts. Participants were assigned to either CR or cognitive defusion intervention and the findings found both techniques to be effective in reducing negative thoughts. It was also reported that cognitive defusion has greater impact than CR. However, this study presented several limitations. Firstly, the researcher implemented a quasi-experimental study but did not clarify the group allocation protocol. Participants inclusion and exclusion criteria were not clear. Secondly, the brief interventions were conducted by the researcher alone hence no evidence of a valid intervention process with no mention of the researcher's previous professional training. The third limitation was the study procedure where participants' negative thoughts were measured using statement associations and a self-rating of discomfort derived from the statements. The association between discomfort and negative thoughts were made without proper justification. These limitations should inform readers to interpret the study findings with caution.

Another study comparing the efficacy of CR and imagery rescripting (IR) in treating depression found similar effectiveness between both (Ma & Lo, 2022). Again, only self-report measures were used to measure the depressive symptoms, but the treatment sessions were conducted by a clinician. This finding was further supported by Kanczok et al. (2024) where they compare intervention group (CR and IR) with a control group (treatment-as-usual) for patients with moderate to severe depression. Depressive symptoms were measured using the Hamilton Depression Rating Scale (HDRS-21), a clinician measured scale for depression. They found greater improvements in the intervention group compared to control, adding insights into cognitive-based and imagery-based intervention in treating depression. However, findings from these studies did not inform the effectiveness of CR alone. As reported by Ezawa and Hollon (2023) from their meta-analytic review of CR and the psychotherapeutic effect, more research is needed despite the accumulating encouraging evidence. Their report suggests further implications for clinical training and a need for a clear process in implementing CR for a uniform intervention.

Santos et al. (2024) recently published a scoping review on implementing CR for depressive symptoms and reiterated that CR is effective in reducing depressive symptoms, however the implementation steps were often not clear. They reviewed seven articles and were able to group the steps outlined into six stages based on the similarities in the activities' goal. These are useful as a future guideline for clinicians and researchers in implementing CR intervention. The six stages are:

1. Start: Presentation of CR technique
2. Explore: Explore emotions, feelings, thoughts
3. Identifying: Identify and record dysfunctional thoughts
4. Comprehension: Assess and examine dysfunctional thoughts
5. Changing dysfunctional thoughts
6. Finalizing: Prevent relapse and self-management of thoughts

1.3 Depression and Brain Activities

EEG is a widely used neuroimaging tool that records brain wave activity with excellent temporal resolution. Its non-invasive nature, affordability, portability, and ability to capture rapid neuronal oscillations make it especially suitable for clinical and research settings focused on psychiatric populations such as those with MDD (Newson & Thiagarajan, 2019; Senkler et al., 2025; Zhang et al., 2021). Among various EEG paradigms, resting-state EEG (rs-EEG) – measured while the subject is relaxed and not engaged in any task – has emerged as a valuable method to investigate underlying neural mechanisms of depression. Comprehensive reviews, such as Newson and Thiagarajan (2019), have demonstrated consistent alterations in resting-state EEG frequency bands across several psychiatric disorders, including MDD, highlighting its diagnostic potential. Park et al. (2021) further supported this by showing that machine learning models trained on rs-EEG features could successfully differentiate between major psychiatric disorders, including depression, with high accuracy. More recently, Senkler et al. (2025) emphasized the growing utility of portable EEG in mental health research, particularly in ecologically valid, real-world settings – showing its relevance for studying urban mental health and depressive symptoms in natural environments.

A growing body of evidence has reported frequency-specific alterations in individuals with MDD. Zhang et al. (2021) found that individuals with depression showed significantly higher absolute power in the theta (4–8 Hz) and alpha2 (10–13 Hz) bands compared to healthy controls. Özçoban and Tan (2025) further supported this by demonstrating increased absolute theta power across frontal, central, parietal, and occipital regions, along with reduced alpha power in MDD participants, highlighting the altered spectral dynamics characteristic of depression. Similarly, Li et al. (2024) found that increased theta power spectral density (PSD), elevated theta–beta ratios, and altered frontal–parietal phase locking values (PLV) were significantly associated with depressive states, even in subclinical populations. Additionally, Lechner and Northoff (2024) emphasized abnormal resting-state phase dynamics – particularly within the alpha and theta bands – as a differentiating neurophysiological marker between MDD and bipolar disorder. However, the patterns of changes remain inconsistent across different brain regions, underscoring the heterogeneity of neural signatures in depression.

Kaushik et al. (2023) suggested that rs-EEG data may be superior to task-based EEG for predicting vulnerability to depression, especially when identifying biomarkers linked to neural predispositions. Their findings indicated that individuals more vulnerable to depression exhibited increased activity in the left frontal lobe and decreased activity in the right frontal and occipital regions. Interestingly, among the various EEG frequency bands analysed, delta activity (0.5 – 4 Hz) emerged as a key differentiator between high and low vulnerability groups. Additionally, their study employed advanced analytical techniques such as evolutionary algorithms and found that features like Higuchi fractal dimension, phase lag index, and coherence were highly informative in detecting depressive risk – though consensus on optimal biomarkers remains unsettled.

Liu et al. (2022) reported further findings in EEG oscillatory patterns in depression. They found increased beta and gamma power in the frontal and temporal regions of MDD patients. This elevation in high-frequency activity may be related to hyperarousal or disrupted cognitive control. Additionally, theta activity was reduced in the central-parietal regions of depressed individuals during resting-state conditions, which may reflect impairments in attentional processes typically associated with this band. Moreover, MDD patients demonstrated significantly increased long-range temporal correlations (LRTC) in the alpha band, suggesting altered temporal dynamics of brain activity. LRTC refers to persistent, structured patterns in EEG signals over time. In depression, increased LRTC – especially in alpha waves – may indicate less flexible brain dynamics, which could underlie cognitive and emotional inflexibility, potentially reflecting the rigidity of negative thought processes.

Alpha rhythms have gained increasing attention as potential biomarkers of depression. In a recent study, Zhou et al. (2023) found that individuals with more severe self-reported depressive symptoms tended to have lower alpha peak amplitudes and higher alpha peak frequencies during resting-state EEG. In other words, as depression severity increased, the strength (amplitude) of alpha waves decreased, while their speed (frequency) increased. These results suggest that changes in the shape and characteristics of alpha activity may reflect the underlying severity of depressive symptoms. This highlights the potential utility of alpha peak features as objective neural markers to support clinical assessment and diagnosis of depression.

Taken together, these studies demonstrate that resting-state EEG reveals consistent alterations in multiple frequency bands among individuals with depression. While findings vary due to methodological and sample-related differences, alterations in alpha and theta bands have been the most consistently reported and theoretically meaningful in relation to depressive symptoms. Theta activity is often elevated, and has been linked to increased internal focus and ruminative thought processes (Liu et al., 2023; Tan et al., 2024; Wang et al., 2022). Alpha rhythms, on the other hand, are typically reduced in power in frontal and parietal areas (Özçoban & Tan, 2025; Wang et al., 2024; Zhang et al., 2021), and changes in alpha peak amplitude and frequency have been associated with depression severity (Zhou et al., 2023). Given their relevance to both cognitive and emotional regulation, this study focuses specifically on alpha and theta activity as neural markers to capture the neurophysiological impact of cognitive restructuring. These two frequency bands offer a robust and interpretable window into the resting-state brain dynamics associated with depression.

1.4 Cognitive and Emotional Significance of Alpha and Theta Bands

Alpha and theta oscillations have distinct yet complementary roles in cognitive and emotional processing. Alpha rhythms (8–13 Hz), particularly in the frontal cortex, are thought to reflect inhibitory control and internal focus (Xie et al., 2024; Zhang et al., 2020). Lower alpha power in depressed individuals may indicate hypervigilance, cognitive overload, or difficulty suppressing negative internal states (Zhou et al., 2023). On the other hand, abnormally high frontal alpha – especially in the left hemisphere – suggests reduced cortical engagement, a hallmark of motivational withdrawal in depression.

Wang et al. (2024) examined further the role of resting-state alpha-band activity as a neural marker of cognitive functioning in individuals with MDD, using both EEG and the MATRICS Consensus Cognitive Battery (MCCB). Their findings revealed that MDD patients exhibited significantly reduced alpha power across multiple scalp regions, particularly in the frontal and parietal areas, compared to healthy controls. Importantly, reduced alpha activity was correlated with impairments in attention, working memory, and processing speed as measured by the MCCB. This study reinforces the interpretation of alpha power as an index of cortical idling or disengagement, with lower alpha reflecting increased cognitive effort or dysregulation in depressive states. It also suggests that alpha rhythms serve not only as emotional markers but also as meaningful indicators of cognitive performance, making them particularly relevant for studies like the present one that aim to evaluate cognitive-emotional shifts following psychological interventions.

Theta oscillations (4–7 Hz) are often associated with emotional regulation, working memory, and internal attention. In depression, increased theta in midline frontal and parietal regions has been linked to ruminative processing and impaired attentional flexibility (Gradwohl et al., 2024; Wang et al., 2022). However, increases in frontal theta post-treatment may also reflect adaptive emotional processing or increased self-referential thought integration, especially when accompanied by clinical improvement (Liu et al., 2022).

Abid et al. (2024) explored the associations between EEG oscillations – specifically theta and beta power – and positive affect, with a focus on the mediating role of emotion regulation strategies. In a non-clinical adult sample, they found that higher resting-state theta power was positively associated with the use of cognitive reappraisal and, in turn, with greater positive affect. Conversely, beta activity was more strongly linked to suppression strategies and lower levels of positive affect. These findings support the idea that theta power is closely tied to adaptive internal cognitive processes, such as reflective emotional processing and re-evaluation of negative thoughts – core components of cognitive restructuring. The study adds further weight to the use of theta power as a psychophysiological correlate of positive emotion and emotion regulation ability, especially in therapeutic contexts that involve altering maladaptive thought patterns.

Dell'Acqua et al. (2021) investigated resting-state functional connectivity in individuals experiencing dysphoria, a subclinical form of depression, using EEG coherence and phase-locking analyses. Their study revealed significantly increased functional connectivity within the alpha and theta bands, especially between frontal and posterior brain regions, in dysphoric participants compared to non-dysphoric controls. These findings suggest a heightened internal focus and possibly ruminative processing, which are commonly seen in early or mild depressive symptoms. The results further support the interpretation that excessive theta activity and altered alpha coherence may reflect inefficient emotion regulation and sustained self-referential processing. In the context of cognitive restructuring, a reduction or normalization of such connectivity patterns might indicate therapeutic progress, particularly as clients begin to challenge and shift entrenched cognitive-emotional loops. This aligns with the present study's focus on changes in alpha and theta power as potential markers of clinical and cognitive improvement.

Thus, examining changes in alpha and theta activity can yield insight into both the symptomatic state and the neural mechanism of therapeutic change, particularly when analysed within a focused region such as F3. This study contributes to the growing body of evidence suggesting that changes in resting-state EEG power – particularly in these two bands – may serve as neural markers of clinical recovery in depression.

1.5 EEG Electrode Placement and Regional Significance

EEG measures electrical activity of the brain via electrodes placed on the scalp. These electrodes detect the synchronous firing of neuronal populations and record the resulting voltage fluctuations in different frequency bands. The placement of EEG electrodes is standardized using the 10–20 international system, a widely adopted protocol that ensures consistent and reproducible positioning of electrodes across individuals and studies. In this system, electrodes are named according to the brain regions they overlay – such as frontal (F), central (C), parietal (P), occipital (O), and temporal (T) – and are labeled with odd numbers for the left hemisphere and even numbers for the right, while midline electrodes are denoted with a "z" (e.g., Cz, Fz) (Acharya & Acharya, 2019; Sazgar & Young, 2019).

The choice of electrode sites in EEG research is typically guided by the research question and the brain regions implicated in the psychological or neurological processes under study. For example, frontal electrodes (e.g., F3, F4, Fz) are commonly examined in studies related to emotion regulation, executive function, and mood disorders, whereas parietal and occipital electrodes are more often involved in studies of visual processing and attention (Dickey et al., 2024; Gao et al., 2023; Metzen et al., 2021; Singh & Singh, 2021). By analysing oscillatory activity at specific electrode sites, researchers can infer the functional engagement of underlying cortical regions. This makes EEG particularly valuable for investigating psychiatric conditions such as

MDD) where disruptions in regional brain activity – especially in the frontal cortex – are commonly observed (Greco et al., 2021; Liu et al., 2022; Mahato & Paul, 2018; Newson & Thiagarajan, 2019; Park et al., 2021).

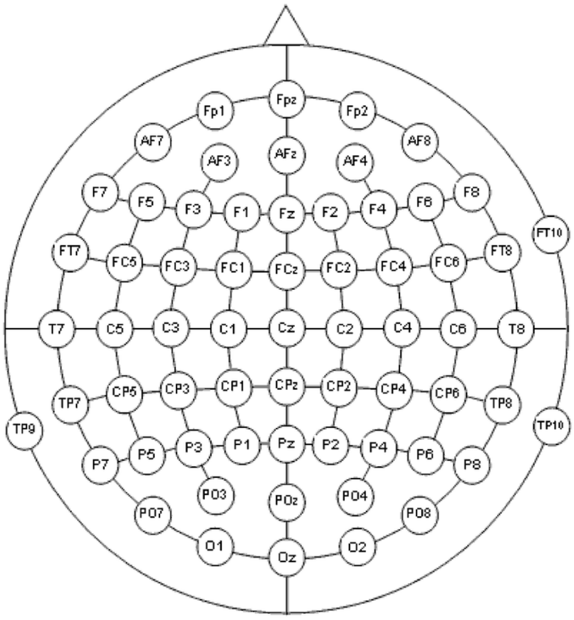

Figure 1 Positions of a 64-channel EEG electrode based on the 10-20 international system (Demin et al., 2016)

The selection of specific electrodes becomes even more important in clinical or psychotherapeutic studies aiming to track the impact of psychological interventions on brain function. Because different cortical areas support different psychological functions, electrode selection must align with the theoretical framework guiding the intervention. In the context of depression, regions involved in emotional regulation, self-referential thinking, and motivation – such as the dorsolateral prefrontal cortex (DLPFC) – are of particular interest, and are typically accessed via frontal scalp electrodes (Friedman & Robbins, 2021; Nejati et al., 2021). These regions are also implicated in the mechanisms of action of cognitive restructuring, which targets maladaptive cognitions and promotes more adaptive patterns of thought and behaviour (Chen et al., 2023; Friedman & Robbins, 2021; Nejati et al., 2021).

In this study, EEG data were primarily analysed from the F3 electrode, which corresponds to the left dorsolateral prefrontal cortex (DLPFC) based on the international 10–20 electrode placement system. This region was chosen due to its well-established role in emotional regulation, cognitive control, and approach-related motivation, all of which are commonly disrupted in individuals with MDD (Kupferberg & Hasler, 2023; Villalobos et al., 2021). The left DLPFC, in particular, has been implicated in the generation and regulation of positive affect and goal-directed behaviour, and hypoactivation in this area has been consistently reported in individuals with depression (Friedman & Robbins, 2021; Hu et al., 2021; Int-Veen et al., 2023; Pizzagalli & Roberts, 2021).

One of the most frequently studied EEG biomarkers in depression is frontal alpha asymmetry (FAA), which reflects the difference in alpha power between homologous left and right frontal regions (e.g., F3 vs. F4) (Dharmadhikari et al., 2019; Luo et al., 2025; Zsigo et al., 2025). Increased alpha power in the left frontal region (F3) relative to the right (F4) is interpreted as reduced cortical activation in the left hemisphere, a pattern that has been associated with depression, anhedonia, and diminished approach motivation (Nelson et al., 2017; Riddle et al., 2022; Zotev et al., 2020). And although this present study focuses on absolute power rather than asymmetry indices, changes in left frontal alpha and theta activity remain meaningful indicators of cortical engagement, particularly in relation to cognitive restructuring, which targets maladaptive thought patterns often mediated by prefrontal regions.

Additionally, recent EEG studies have highlighted the importance of frontal theta and alpha oscillations in capturing the neurophysiological impact of psychotherapeutic interventions. For example, increased frontal theta activity has been observed in depressed patients and has been associated with rumination and internal cognitive focus (Amico et al., 2023; Hsu et al., 2021; Wang et al., 2022). Meanwhile, changes in frontal alpha power, especially at F3, have been linked to therapeutic improvement and emotional regulation during cognitive-behavioural interventions (Deng et al., 2021; Kaushik et al., 2023; Luo et al., 2023; Xu et al., 2018).

By selecting the F3 electrode for analysis, this study seeks to target a region with strong theoretical and empirical relevance to both the symptom profile of depression and the mechanism of change proposed by cognitive restructuring. Measuring resting-state alpha and theta power at F3 allows for a focused yet meaningful exploration of how structured psychological intervention may modulate underlying brain dynamics associated with depressive symptomatology.

1.6 EEG as a Tool for Monitoring Psychotherapy Outcomes

EEG is increasingly being used to evaluate the neural correlates of psychotherapeutic change, particularly in depression. Its high temporal resolution, portability, and relatively low cost make it especially suitable for repeated within-subject measurements, such as pre- and post-treatment comparisons. Emerging studies suggest that EEG features – such as changes in alpha, theta, and beta power – can reflect the neural mechanisms underlying therapeutic interventions like CBT, mindfulness-based cognitive therapy, and cognitive remediation (Castelluccio et al., 2020; Newson & Thiagarajan, 2019; Wang et al., 2022).

For instance, Tacca et al. (2024) explored the integration of virtual reality (VR) and EEG in a remote psychotherapy system designed to treat depressive symptoms. Their study examined the feasibility and effectiveness of a novel, immersive intervention that combined interactive VR-based therapeutic exercises with real-time EEG monitoring. The system provided neurofeedback to guide and personalise therapeutic content, enabling users to engage in targeted emotional regulation exercises while their brain activity was continuously assessed. Over the course of multiple sessions, participants exhibited significant reductions in self-reported depressive symptoms, which were paralleled by measurable changes in resting-state EEG patterns – particularly in frontal alpha and theta bands. The study demonstrates the growing potential of EEG not just as a passive measurement tool but as an active component of adaptive, tech-enhanced psychotherapy delivery. This is especially relevant for modern approaches that aim to make mental health interventions more scalable, accessible, and responsive to individual neurophysiological states.

Zajecka et al. (2024) conducted a pilot study evaluating an EEG-based monitoring tool to detect acute clinical and cognitive changes in adults with MDD undergoing pharmacological treatment with vortioxetine. EEG recordings were collected before and after treatment sessions, and changes in spectral power – particularly in the theta and alpha frequency bands – were analysed alongside standardised depression and cognitive assessments. The findings revealed a significant correlation between changes in frontal EEG markers and both mood improvement and enhanced cognitive function (i.e., working memory, processing speed). While the intervention in this study was pharmacological rather than psychotherapeutic, the results highlight the capacity of EEG to sensitively track short-term clinical shifts in MDD populations. This brings forward EEG's utility as a dynamic, non-invasive monitoring tool that can be extended to psychotherapy research to detect moment-to-moment changes in emotional and cognitive states that may not be captured through self-report measures alone.

An advanced application of EEG as a tool to monitor mental health was proposed by Liu and Zhao (2025) by incorporating deep learning algorithms to enhance signal robustness and classification accuracy. Their study focused on developing and validating neural network models that could automatically extract meaningful EEG features – particularly from noisy, real-world datasets – and accurately detect depressive states across diverse individuals. By training models on large resting-state EEG datasets, the researchers were able to identify exact patterns in alpha and theta activity that corresponded with depressive symptom severity. Importantly, their approach also allowed for personalised modelling, adapting predictions to the individual's baseline neurophysiological profile. This innovation holds promise for integrating EEG-based biomarkers into routine mental health care and suggests that EEG, when supported by advanced computational tools, could play a key role in tracking psychotherapy outcomes with high temporal and individual sensitivity.

In the current study, EEG served as a neurophysiological indicator of treatment progress, offering a complementary perspective to self-report measures. Focusing on alpha and theta power provided a frequency-specific view of cognitive and emotional engagement before and after cognitive restructuring. This aligns with the broader trend of integrating neuroimaging into psychotherapy research to bridge the gap between brain and behaviour.

CHAPTER 2

OBJECTIVES

2.1 Objectives

General Objectives

To explore the effect of cognitive restructuring on brain activities and depressive symptoms in individuals with depressive disorders using a case series approach.

Specific Objectives

a) To compare the changes in alpha and theta brain wave activities in patients with depressive disorders before and after cognitive restructuring intervention.
b) To compare the changes in self-reported depressive symptoms in patients with depressive disorders before and after cognitive restructuring intervention.
c) To examine the relationship between changes in resting-state EEG activity and improvements in depressive symptoms.

CHAPTER 3

GENERAL METHODS

3.1 Study Design

This study utilised a case series design with pre- and post-intervention assessments to examine the effects of cognitive restructuring on depressive symptoms and resting-state brain activity. The design allowed each participant to serve as their own control, enabling detailed within-subject comparisons over time. Participants were recruited from the Klinik Psikologi at Hospital Pakar Universiti Sains Malaysia (HPUSM) and were selected based on specific inclusion criteria.

3.2 Inclusion/Exclusion Criteria

Participants were included in the study if: (1) age between 18 and 65 years; (2) a primary diagnosis of depressive disorder according to DSM-5-TR criteria; (3) a baseline score of ≥18 on the 17-item Hamilton Depression Rating Scale (HDRS-17) (see Appendix A) and ≥10 on the Patient Health Questionnaire (PHQ-9) (see Appendix B), indicating moderate to severe depression; (4) ability to provide informed consent and attend scheduled sessions. Exclusion criteria included (1) current substance use disorders, (2) psychotic symptoms, (3) neurological illness, and (4) previous exposure to cognitive restructuring.

3.3 Cognitive Restructuring Protocol

This study employed a structured cognitive restructuring intervention adapted from the framework proposed by Santos et al. (2024) (see Appendix F). The intervention is designed to be delivered across six individual sessions, with each session lasting approximately 60 minutes and conducted twice weekly over a span of three weeks. Sessions were conducted face-to-face by a trainee clinical psychologist under the supervision of an experienced clinical psychologist.

The intervention follows a phased progression, where each session builds on the previous one to promote cognitive and emotional change. The key focus of the intervention is to help participants identify and challenge maladaptive thought patterns and to develop more balanced and adaptive thinking styles. The planned session content are as follows:

Session 1 : Psychoeducation and Introduction to Cognitive Restructuring

Introduce the cognitive model of depression, explain the purpose and goals of CR, and help participants understand the link between thoughts, emotions, and behaviours.

Session 2 : Identifying Automatic Thoughts

Guide participants to observe and record their automatic thoughts that occur in response to distressing events or situations.

Session 3 : Exploring Cognitive Distortions

Introduce common cognitive distortions (e.g., overgeneralisation, catastrophising) and help participants learn to recognise these patterns in their thinking.

Session 4 : Challenging Unhelpful Thoughts

Facilitate structured exercises using Socratic questioning and evidence evaluation to challenge negative automatic thoughts and underlying beliefs.

Session 5 : Developing Alternative and Balanced Thoughts

Support participants in generating healthier, more balanced perspectives and coping statements to replace maladaptive cognitions.

Session 6 : Relapse Prevention and Consolidation

Review key skills learned throughout the intervention, develop a personalised relapse prevention plan, and encourage continued practice of CR strategies in daily life.

Each session follows a consistent structure, including a brief check-in, review of prior session content, introduction of new material, guided cognitive exercises, and a session summary. Homework assignments are planned to reinforce learning between sessions. This protocol is designed to promote cognitive flexibility and symptom reduction among individuals with depressive disorders.

3.4 EEG Data Recordings

EEG recordings were performed before and after the cognitive restructuring sessions. For this study, the EEG data acquisition system used ANT Neuro with a 64-

channel cap and gel-based EEG. The EEG data collected in this study were processed and analysed offline using MATLAB R2020a in combination with the EEGLAB toolbox (version 14.1.1b). The data were sampled at 500 Hz, and several preprocessing steps were performed to ensure the quality and reliability of the EEG signals before statistical analysis.

EEG data underwent a standardized preprocessing pipeline to ensure high-quality, artefact-free signals for analysis. Raw signals were band-pass filtered (0.1–45 Hz), re-referenced to a common average, and checked for noisy or missing channels, which were interpolated. The data were segmented into eyes-closed and eyes-open resting-state conditions, with manual and Independent Component Analysis (ICA-based) artifact removal procedures applied to eliminate non-neural activity. The data were segmented to 2 sec epochs. A custom MATLAB script automated feature extraction, focusing on mean absolute power in the alpha (8–13 Hz) and theta (4–7 Hz) bands at a selected frontal site. The final dataset was exported to SPSS for statistical analysis. A more detailed description of each step is provided in Chapter 4.

3.5 Clinical Outcomes

Clinical outcomes were assessed using the Beck Depression Inventory Malay Version (BDI-Malay) (Mukhtar & Oei, 2010) (see Appendix C), Beck Anxiety Inventory Malay Version (BAI-Malay) (Mukhtar & Zulkefly, 2011) (see Appendix D), and Automatic Thoughts Questionnaire Malay Version (ATQ-Malay) (Oei & Mukhtar, 2008) (see Appendix E), administered before and after CR intervention. These standardised self-report measures evaluated changes in depressive symptoms, anxiety levels, and the frequency of negative automatic thoughts. Psychometric properties and details of the questionnaires used were explained in the manuscript in Chapter 4. Pre-post score differences provide indicators of the intervention's effectiveness on emotional and cognitive functioning.

3.6 Neurophysiological Outcomes

Neurophysiological outcomes were assessed using resting-state EEG recordings in both eyes closed and eyes open condition obtained before and after the CR intervention. EEG data focused on the analysis of absolute power in the alpha (8–13 Hz) and theta (4–7 Hz) frequency bands, which are commonly associated with emotional regulation and depressive symptomatology. Pre-post comparisons of spectral power on individual level provided objective indicators of changes in brain activity related to the intervention's neurophysiological effects.

CHAPTER 4

MANUSCRIPT

This chapter presents the main findings of the study in the form of a manuscript prepared for journal submission. As such, some of the content – particularly in the introduction, literature review, and methodology sections – may overlap with information presented in earlier chapters. This repetition is intentional and serves to ensure the manuscript stands independently as a complete and publishable document. Readers and examiners are advised to note that while certain sections may appear familiar, they are included here to meet academic publishing standards.