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Neurofeedback during pregnancy

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Pregnancy can be an emotionally challenging time for many expecting mothers as they become more susceptible to stressors (e.g., pregnancy-specific stress such as foetal health and birth outcomes. As well as issues concerning finance, relationships and discrimination.) due to the biological, psychological and social changes that occur during pregnancy [1,2,13]. Anxiety and depression are a particular concern as various research demonstrates that ~ 1 in 5 pregnant women will have an anxiety disorder, 10-14% will meet the criteria for major depression disorder (MDD), whereas 25-50% will exhibit symptoms of anxiety and depression that do not meet the full diagnostic criteria [1].

Why is anxiety during pregnancy of concern?

Acute and chronic stress cause an imbalance in homeostasis and thus increase the likelihood of pregnancy issues, e.g., neonatal comorbidity and preterm birth that is further associated with long-term complications in vision, neuro-developmental delays and short-term cardiovascular, neurological and metabolic complications [1,3,13].

For example, physically stressed mothers (e.g., they exhibit high blood pressure) are at a higher risk of delivering infants with decreased heart rate movement coupling (this can be indicative of the central nervous system developing at a slower rate). Whereas psychologically stressed mothers may undergo more birth complications [4].

Regarding the mother's wellbeing, anxiety increases the frequency of nausea, vomiting and the likelihood of developing depression [2,10].

Stress induced birth complications are partially due to the increase of various pro-inflammatory cytokines alongside the decrease of anti-inflammatory cytokine IL-10. This imbalance in inflammatory markers can negatively effect the mother's immune system, thereby increasing the likelihood of a poor pregnancy outcome [1].

The recent pandemic has led to an increase in stress, anxiety and depression, especially within women [2,5,7,8]. Thus, several studies have highlighted the importance of monitoring the mental health of antenatal women after heightened anxiety levels in expectant mothers have been observed.

> Several studies have demonstrated neurofeedback training (NFT) efficacy in decreasing anxiety and related symptoms [17,22,24,27,28,29,30].

Targeting anxiety with Neurofeedback

Oscillations acquired from the brain are closely tied to behavioural arousal, i.e., low frequency oscillations (such as delta, theta and alpha) are characteristics of low cortical and behavioural arousal due to reduced neuronal firing and excitability. Vice versa, high frequency oscillations may connote high cortical and behavioural arousal [26].

States of lower arousal are ensued by decreased awareness of stimuli in one's environment. For example, patients with PTSD are reported to exhibit higher power of beta rhythms, i.e., high frequency oscillations, alongside reduced alpha power rhythms [26,28,29]. Whilst increased high-frequency gamma band activities (again, very high frequency oscillations) are observed in generalised anxiety disorder (GAD) [27].

> Similar to many studies, Wang et al observed that neurofeedback successfully reduced high-beta at the parietal cortex which was accompanied by reduced anxiety and depression in their patients [17].

In further support of this concept, Liu and colleagues observed an increase in SMR (this is a low beta frequency that has been linked to relaxed focus and improved performance) within post-training EEG assessments – this increase in

SMR resulted in reduced anxiety after two weeks of neurofeedback training.

Study	Participants	Number of Sessions	Duration of Sessions	Training Protocol and Site	Results
Rice et al 1993	38 patients with GAD	8 – 2x per week	-	2 groups: Increase alpha Decrease alpha	• All groups had **significant improvement in their anxiety scores** (STAI-Trait test) • **Reduction in anxiety was maintained 6 weeks post-treatment** • Alpha up group further displayed **reduced heart rate reactivity to stressors**
Van der Kolk et al 2016	52 adults diagnosed with treatment resistant PTSD	24 – 2x per week	30 minutes	Decrease Delta-Theta (2-6Hz) Decrease beta (22-36Hz) Increase high alpha (10-13Hz) T4	**Significant PTSD symptom reduction** **Improved emotional regulation**
Noohi et al 2017	30 adults diagnosed with PTSD	25 – 4x per week	30-40 minutes	Increase Theta (4-8Hz) over Alpha Mid and Frontal regions	**Improvements in depression but significantly more improvement in PTSD symptoms**
M. Gadea et al 2020	32 healthy males	1 session	30 minutes	Inhibit Theta Increase SMR Cz	Experiment group showed: • **Reduced feelings of tension/anxiety** that wasn't present in controls • **Decreased anger/hostility** in both groups but significantly higher in experiment group
S. Liu et al 2022	33 healthy subjects	6 – 3x per week	-	Increase SMR C3	• NFT **decreased anxiety levels** in healthy subjects •EEG showed increased SMR power

Why is depression during pregnancy of concern?

Similar to anxiety, depression or the continuous use of SSRIs (selective serotonin reuptake inhibitors) during pregnancy are reported to result in preterm birth rates surpassing 20%. Furthermore, both anxiety and depression increase the likelihood of post-partum depression [10].

This is significant to note as the goal of improving depression and anxiety isn't just to support the health of mother and foetus during pregnancy - but to also mitigate the downstream issues these disorders can evoke on parenting and attachment styles as well as the child's emotional regulation capabilities [1,6].

For example, the children of very anxious mothers are twice as likely to develop ADHD [10].

> Once again, Neurofeedback training has been demonstrated to be effective in the treatment of depression [17,18,19,20,21,22,23].

Targeting depression with Neurofeedback

Method 1: Training Alpha asymmetry.

This protocol is widely used for the treatment of depression. The model is based on the consensus that it is predominantly the right prefrontal cortex that modulates positive emotions and approaching behaviour patterns.

The training of positive emotions involves either:

•   Increasing left frontal beta while decreasing beta on the right, OR

•   Increasing right frontal alpha (i.e., suppressing right frontal activity) while decreasing alpha activity in the left

The alpha band is of particular interest for depression-targeted NFT as occipital alpha is indicative of a calm resting state whereas frontal alpha is involved in emotion and motivation. For example, Choi and colleagues observed that alpha training resulted in higher levels of frontal alpha power and improvements in depression and automatic thoughts within their subjects [31].

Study	Participants	Number of Sessions	Duration of Sessions	Training Protocol and Site	Results
S. Wang et al 2019	87 patients with comorbid MDD and anxiety	10 – 2x per week	15 minutes	Group 1: Increase frontal Alpha asymmetry F3 and F4 Group 2: Inhibit high beta P3 and P4	• Both NFT groups showed **positive improvements in depression and anxiety** (according to BDI-II and BAI scores) • Beta group was most effective at reducing high beta at parietal cortex, while high beta increased in control group
J. Gomes et al 2016	Case study (female aged 29)	20	N/A	Increase SMR at C4 Increase alpha/beta (23-38) ratio at P4	**Marked improvement of anxiety, depression and sleep quality, in addition to improved executive functioning**
D. Hammond 2000	8 adults diagnosed with depression	20	30 minutes	Inhibit slow alpha and theta Increase Beta (15-18Hz for the first 20 minutes. Then 12-15Hz in last 20 minutes)	Substantial improvements: • 1 patient improved from severely depressed to normal • 2 patients improved from seriously depressed to normal • 3 patients improved from severe-moderate depression to normal • 1 patient improved from severely depressed to mild depressed • 1 drop out due to busy lifestyle

Method 2: Alpha-Theta (A-T) alongside high beta power or SMR beta training.

This protocol rewards greater occipital theta power over alpha. The aim is to attain deep relaxation, diminish stress and promote easier retrieval of unconscious thoughts. The benefits of this protocol were established in the 90s during the treatment of substance dependence. It has been suggested that the positive results were due to the protocols impact on endorphin levels and its ability to improve subjective estimates of depression [18,19].

Since then, alpha/theta training has shown promising results on an array of personality scores (e.g., Millon Clinical Multiaxial inventory and the Minnesota multiphasic personality inventory) by inducing a shift towards more warm-hearted, emotionally stable, satisfied, relaxed and self-positive attributes [20]. While increasing low beta (SMR) oscillations improves the lack of motivation and executive functioning often observed in depression.

Study	Participants	Number of Sessions	Duration of Sessions	Training Protocol and Site	Results
J. Raymond 2005	12 healthy medical students with high PSQ-80 scores (measures withdrawal)	10 – 2x per week	20 minutes	Increase theta Reduce alpha Pz	Experiment group showed: • **Increased levels of energy and confidence** • **More positive mood**
E. Cheon et al 2015	77 adult patients with Axis I disorder	Varied – Over 5 sessions for ~70%	Varied – 10 minutes for ~50%	Increase theta and reduce alpha Pz Increase SMR (if also anxious) T4 Increase Beta (if not anxious) F3 Increase Beta (if lethargic) T3 or F3	• NFT improved the severity of patient's withdrawal scores • **Improved depression, anxiety, self-esteem, hostility, attention and hyperactivity** based on Hill-Castro checklist
Y. Lee et al 2019	24 adults diagnosed with treatment resistant MDD	24 - 2x per week	30 minutes beta 30 minutes A/T	1 increase Beta at T3 5 increase Beta at F3 6 increase SMR at T4 All beta training was followed by A/T training at Pz	• **Reduction in subjective and objective depression** • **The neurofeedback group obtained significantly better results in their depression scores** (i.e., showed more improvement) compared to the medication-only group
D. Cantor and E. Stevens 2009	16 medication resistant adults with depression	20 – 5x per week	30 minutes	Auditory-visual EEG entrainment at 14Hz Beta	• **Significant reduction of depression** • **Significant EEG changes in cortical regions linked to mood regulation**

Additional Neurofeedback-mediated pregnancy support: Increasing Resilience

The most vital news is that not all expecting mothers facing stress will have negative pregnancy outcomes.

> Hogue and his team highlighted that effective coping in pregnant women can reduce the negative effects of stress, such as preterm birth. While Ineffective coping allows for stress to cause homeostatic imbalance and its associated risks [11].

Similarly, Xuemei et al demonstrated that resilience during pregnancy acts as a protective factor for mitigating or diminishing the impacts of anxiety and depression [12].

> Neurofeedback training can support expectant mothers with anxiety and depression to improve physiological and neuronal resilience and promote a healthy nervous system that will act as a positive tuning fork for the baby: calm mother equals calm baby. Both emotional and physiological resilience can be further enhanced with biofeedback.

1.   The Mindfulness approach

Mindfulness fosters resilience by enhancing present focus which facilitates effective decision-making and actions, increasing flexibility which enables individuals to adapt to present obstacles and improving self-control [32,33].
Whether it is a result of increased resilience or a further by-product of practicing mindfulness; Meta-analyses of 17 studies in 2016 and 14 studies in 2017 demonstrated that mindfulness interventions also improved depression, anxiety and stress [14,15]. The power of mindfulness is that it enables individuals to be aware of their internal states. This awareness allows for a better understanding and sometimes control over one's circumstances. Neurofeedback acts similarly to meditation by providing a mirror through which the brain can observe itself and make vital adjustments to enhance self-regulation.

Additionally, neurofeedback training (NFT) in combination with mindfulness practices is reported to enhance results. Hunkin and team showed that participants receiving auditory feedback via EEG NFT during meditation entered a

deeper state of mindfulness and had reduced incidences of mind wandering compared to the controls that meditated without feedback [16]. Concomitantly, Arpaia's team found an increase of emotional acceptance within their cohort that received neurofeedback in combination with emotional acceptance-based mindfulness training [17].

2. **Heart Rate Variability (HRV) training**

HRV training has been demonstrated to increase resilience to stress during nonstress periods as well as to traumatic events [34]. As posited by Hogue et al and Xuemei et al, increased resilience attenuates stress induced birth complications.

In two studies comprising pregnant women (the first consisted of women at threat of preterm labour while the latter entailed women in the early postpartum period), HRV was demonstrated to induce positive results.

For the antenatal group at risk of preterm birth, women that received HRV training exhibited a reduced perception of chronic stress and a lower rate of preterm birth compared to the controls. Whereas in the postpartum cohort, HRV training improved scores in the Edinburgh postnatal depression scale, meaning that HRV reduced depression. A further supporting study reported that HRV training reduced anxiety symptoms and improved overall psychological well-being in their pregnant cohort [1].

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