THE ASIAN EDUCATIONAL THERAPIST

ISSN: 2972-4104, Volume 2, Issue 3, Page 53 - 73

REVIEW ARTICLE

Neural Correlates of the Big Five Personality Traits: Understanding the Brain Basis of Openness, Conscientiousness, Extroversion, Agreeableness, and Neuroticism

Kok-Hwee, CHIA[a1] and Meng-Kiat, TAN[a2]

[a]Merlion Paediatric Therapy Clinic, Singapore

[1] Managing Principal Educational Therapist

[2] Applied Neuroscientist

Article DOI: https://doi.org/10.64663/aet.42

Corresponding author's email: dr.chia@merlionpaediatric.sg

***Cite as**: Chia, K. H., & Tan, M. K. (2024). Neural correlates of the big five personality traits: Understanding the brain basis of openness, conscientiousness, extroversion, agreeableness, and neuroticism. The Asian Educational Therapist, 2(3), 53-73.*

ABSTRACT

This article explores the neural underpinnings of the Big Five Personality Traits (BFPTs) - Openness to Experience [O], Conscientiousness [C], Extroversion [E], Agreeableness [A], and Neuroticism [N] or the acronym OCEAN - by examining recent studies in neuroscience. Research reveals distinct brain regions associated with each trait, shedding light on their neural bases. Conscientiousness is linked to increased activity in the prefrontal cortex, reflecting its role in self-regulation and goal-directed behavior. Neuroticism shows associations with the amygdala and other limbic structures, indicating a neural predisposition to emotional reactivity and stress sensitivity. Extroversion is related to the dopamine system and ventral striatum, suggesting its connection to reward processing and social engagement. Openness to Experience correlates with increased connectivity in the default mode network and prefrontal cortex (PFC), supporting its association with cognitive flexibility and creativity. Agreeableness is linked to the temporo-parietal junction (TPJ) and brain areas involved in empathy and social cognition. Understanding these neural correlates provides insights into how personality traits are represented in the brain and influence behavior.

***Keywords:** Big Five personality traits, Brain regions, Neural correlates, Neural underpinnings, Neuroscience studies*

1. INTRODUCTION

According to Rammstedt and John (2020), “[T]he Big Five Inventory (BFI; John et al., 1991; see also John et al., 2008) was developed to assess the most global personality domains in the adult population, the so-called Big Five trait domains: extraversion, agreeableness, conscientiousness, neuroticism (vs. emotional stability), and openness to experiences” (p. 469). The BFI development was very much guided by the core traits common to the various five-factor studies reported in the literature. Beginning with the publication of a brief and prototypical version of the BFI assessment of personality, the present BFI measures “the Big Five domains with 44 short phrases that the respondent answers on a five-point rating scale, ranging from 1 (disagree strongly) to 5 (agree strongly). It is available free of charge for the scientific community (John et al., 2008)” (Rammstedt & John, 2020, p. 469).

The Big Five Personality Traits (BFPTs) are (i) Openness to experience (O); (ii) Conscientiousness (C); (iii) Extroversion (E); (iv) Agreeableness (A); and (v) Neuroticism (N) (John et al., 1991). These five personality traits can be represented by the acronym OCEAN and each is briefly described in Table 1.

Table 1. The Brief Description of BFPTs

Personality Traits	Description
Openness to experience [O]	This personality trait reflects the degree of intellectual curiosity, creativity, and a willingness to engage with novel ideas and experiences.
Conscientiousness [C]	It indicates a person’s level of self-discipline, organization, and reliability in achieving goals.
Extroversion [E]	This personality trait describes the extent to which an individual is outgoing, energetic, and seeks stimulation and social interaction.
Agreeableness [A]	It measures the tendency to be compassionate, cooperative, and trusting toward others.
Neuroticism [N]	This personality trait represents the tendency to experience negative emotions such as anxiety, depression, and mood swings.

Interestingly, these BFPTs are associated with various cortical regions and sub-cortical areas of the human brain and neural pathways, reflecting the complex interplay between brain structure, function, and personality.

2. ASSOCIATION OF BFPTS WITH CORTICAL REGIONS & SUB-CORTICAL REGIONS AND NEURAL PATHWAYS

The human brain in its complexity can be divided and differentiated into four key regions with distinct functions, and understanding these cortical areas can give us insights into how the brain works. These cortical areas are parts of the cerebral cortex - the outermost layer of the brain - which is involved in higher-level functions including perception, cognition, and voluntary movement. The cortex is also referred to as ‘gray matter’ because of its color. It is further divided into different lobes: frontal, parietal, temporal, and occipital (Casillo, Luy, & Goldschmidt, 2020). Each of them is associated with specific functions as shown in Table 2 below.

Table 2. The Four Key Cortical Areas of the Brain

Cortical Areas	Description
Frontal Lobe	It involves reasoning, planning, problem-solving, and motor control.
Parietal Lobe	It processes sensory information and spatial awareness.
Temporal Lobe	It handles auditory processing and memory.
Occipital Lobe	It is primarily responsible for visual processing.

Located beneath the cerebral cortex are the **subcortical areas,** often referred to as 'white matter' due to the myelin sheaths that cover many of the neurons (van der Knaap & Valk, 2005). Generally speaking, these sub-cortical areas are involved in a range of essential functions including emotions, motivation, and basic survival functions. The five key sub-cortical structures include the following (see Table 3):

Table 3. The Five Key Sub-Cortical Areas of the Brain

Sub-Cortical Areas	**Description**
Basal Ganglia	This structure is involved in movement regulation and coordination. It helps in controlling voluntary movements and procedural learning.
Thalamus	It acts as a relay station for sensory and motor signals, directing them to appropriate cortical areas.
Hypothalamus	The structure regulates many autonomic processes such as hunger, thirst, and temperature control. It also plays a role in emotional responses and endocrine system regulation.
Amygdala	It plays a crucial role in processing emotions, particularly fear and pleasure.
Hippocampus	This structure is essential for forming new memories and spatial navigation.

Together, cortical and sub-cortical areas of the brain work in concert to facilitate complex behaviors and processes, integrating higher cognitive functions with basic physiological and emotional responses (see Pessoa, 2022, for detail).

The BFPTs are linked to specific cortical regions, sub-cortical areas, and neural pathways in the human brain, illustrating the intricate relationship between brain structure, function, and personality. Table 4 below illustrates how each of the five BFPTs is associated with or connected to different parts of the brain.

Table 4. The Links between BFPTs and Different Parts of the Brain

Personality Traits	**Main Role**	**Associated Parts of the Brain**
Openness to Experience (O)	Characterized by imagination, curiosity, and creativity	Involves the default mode network (DMN), which includes the medial prefrontal cortex (mPFC), posterior cingulate cortex (PCC), and other interconnected regions. The DMN is active during introspective and creative thinking. Higher openness is associated with greater connectivity and activity within the DMN, facilitating the imaginative and abstract thinking characteristic of this trait.
Conscientiousness (C) (Sources: e.g., Forbes et al., 2014; Huo et al., 2020)	Associated with self-discipline, organization, and goal-directed behavior	Is linked to the prefrontal cortex (PFC), particularly the dorsolateral prefrontal cortex (dlPFC). The dlPFC is critical for executive functions, such as planning, decision-making, and impulse control. Higher conscientiousness may reflect stronger connectivity and greater gray matter volume in these areas, facilitating better self-regulation and control over behavior.

Extroversion (E) (or Introversion)	Involves sociability and positive emotions	Is linked to the reward system, particularly the nucleus accumbens and the orbitofrontal cortex (OFC). The nucleus accumbens, part of the brain's reward circuitry, responds to rewarding stimuli, while the OFC evaluates rewards and makes decisions based on expected outcomes. Higher extroversion is associated with greater activity and connectivity in these reward-related regions, explaining the tendency for extroverts to seek out social interactions and novel experiences.
Agreeableness (A)	Associated with empathy, cooperation, and social harmony	Involves the superior temporal sulcus (STS), temporoparietal junction (TPJ), and ventromedial prefrontal cortex (vmPFC). The STS and TPJ are important for understanding others' intentions and perspective-taking, while the vmPFC is involved in social decision-making and processing moral judgments. Greater activity and connectivity in these areas support the empathetic and prosocial behaviors seen in individuals high in agreeableness.
Neuroticism (N)	Characterized by emotional instability and anxiety	Involves the amygdala, hippocampus, and anterior cingulate cortex (ACC). The amygdala processes emotional responses and fear, often showing increased reactivity in individuals high in neuroticism. The ACC is involved in emotion regulation and detecting conflicts, while the hippocampus is related to stress responses. Overactivity or heightened sensitivity in these areas can contribute to the heightened emotional reactivity and stress sensitivity seen in high neuroticism.

In summary, the BFPTs are underpinned by specific brain regions and neural pathways:

1. Openness to Experience [O]: DMN for introspection and creativity (Blain et al., 2020; Sun et al., 2019).
2. Conscientiousness [C]: DLPFC and other prefrontal areas for self-regulation and planning (Forbes et al., 2014; Huo et al., 2020).
3. Extroversion [E]: Nucleus accumbens and OFC for reward processing and sociability (see Mobbs et al., 2005).
4. Agreeableness [A]: STS, TPJ, and vmPFC for empathy and social cognition (Leiet al., 2015; Owen et al., 2019).
5. Neuroticism [N]: Amygdala, ACC, and hippocampus for emotional reactivity and stress response (Haas et al., 2007; Tzschoppe et al., 2014).

These associations highlight the biological basis of personality, illustrating how variations in brain structure and function can influence individual differences in behavior and thought.

3. NEUROSCIENCE-BASED INTERVENTIONS

Neuroscience-based interventions (NSBIs) are approaches or techniques (see O'Brien, 2021, for detail) designed to influence brain function, structure, or activity to address cognitive, emotional, or behavioral challenges. These interventions are grounded in principles derived from neuroscience, the scientific study of the brain and nervous system. They leverage our understanding of how the brain works to develop strategies that can improve mental health, cognitive performance, and overall well-being.

We have identified five key characteristics of NSBIs (also see Faustino, 2022, for 14 neuroscience-based guiding principles not discussed in this paper) and briefly discussed here. Firstly, we want to reiterate that all NSBIs must be evidence-based. In other words, these interventions are based on scientific research and findings about brain function and behavior. They are designed to align with the current understanding of how different brain regions and systems contribute to mental processes and emotional states. Secondly, we also want to reiterate that the NSBIs must target at the correct or appropriate brain functions. They need to focus on specific brain functions or regions, e.g., enhancing cognitive abilities, regulating emotions, or modifying maladaptive behaviors. For instance, some interventions target the amygdala to reduce anxiety, while others aim to enhance prefrontal cortex activity to improve decision-making. Thirdly, the use of technology and tools in conducting NSBIs today has become inevitable. Many NSBIs involve technological tools that measure or influence brain activity. This can include neurofeedback (Hammond, 2007), brain imaging techniques (Jun & Yoo, 2018), or cognitive training programs. Fourthly, NSBIs often involve strategies to modify thought patterns, behaviors, or emotional responses. Techniques such as Cognitive Behavioral Therapy (CBT; Wenzel, 2017) and cognitive training (Chia & Ng, 2021) are designed to reshape neural circuits involved in these processes. Lastly, we want to emphasize the necessity to personalize and adapt any NSBI to meet individual needs based on specific cognitive or emotional challenges. Personalization ensures that the strategies (often used in neuroprosthetics, i.e., devices that can replace a motor, sensory, or cognitive function that may have been impaired due to an injury or illness; see Borton et al., 2013, for detail) used are effective for the individual's unique brain function and psychological state.

There are many examples of NSBIs. Here we have selected a few for illustration. Among the NSBIs, the neurofeedback (also see Monderer, Harrison, & Haut, 2002; Wanng & Hsieh, 2013) - a widely known technique where real-time brain activity is monitored and used to train individuals - is used to regulate specific brain functions (Hammond, 2007). It can help improve conditions like ADHD, anxiety and/or depression (Hammond, 2005; Niv, 2013). Closer to the neurofeedback (but can be mistaken for it) is the biofeedback, which uses physiological signals (like heart rate or muscle tension) to help individuals gain control over physiological processes, which can affect brain function and emotional regulation (Schwartz & Andrasik, 2017). While both techniques are related, they remain distinct approaches; each targeting different aspects of physiological regulation (Yucha & Montgomery, 2008). The biofeedback involves using electronic monitoring to provide real-time feedback on physiological functions such as heart rate, muscle tension, skin temperature, or breathing (Karavidas et al., 2007; Schwartz & Andrasik, 2017). The goal is to help individuals gain awareness and control over these physiological processes, often to improve health or manage stress. For example, someone might use biofeedback to learn how to lower their heart rate or reduce muscle tension through relaxation techniques (Karavidas et al., 2007). On the other hand, the neurofeedback is a specific type of biofeedback whose focus is on brain activity. It involves monitoring brainwave patterns through electroencephalography (EEG) and providing real-time feedback to help individuals regulate their brain function (Hammond, 2007). Neurofeedback is often used to address issues like ADHD (Niv, 2013), anxiety (Hammond, 2005), or epilepsy (Monderer, Harrison, & Haut, 2002) by training individuals to alter their brainwave patterns to achieve more optimal mental states. To sum it up briefly, biofeedback is a broader approach that includes various physiological systems (heart rate, muscle tension, etc.), while neurofeedback is just a subset of biofeedback specifically targeting brainwave activity and function. Both techniques aim to improve self-regulation and well-being, but they focus on different areas of the body (see Yucha & Montgomery, 2008, for detail).

Next, mindfulness and meditation, though considered traditional and spiritual have been found to be useful practices that can enhance emotional regulation and reduce stress by influencing brain regions involved in attention, emotion, and self-awareness (Marlatt & Kristeller, 1999). Cognitive behavioral therapy (CBT), another good example of a NSBI, is a therapeutic approach that modifies negative thought patterns and behaviors, thereby affecting brain activity related to emotion and cognition (Wenzel, 2017). Overlapping between mindfulness, meditation and CBT is the mindfulness-based cognitive therapy (MBCT; Hibberd & Usmar, 2015). Not forgetting the cognitive training programs (e.g., NeuroLat and Fast ForWord) that offer interesting exercises that are designed to improve specific cognitive functions like memory, attention, or executive function, thereby influencing brain plasticity and connectivity (Chia & Ng, 2021; Genevsky et al., 2010).

Finally, there is always the pharmacological treatments to fall back on when all other techniques do not seem to work well for some individuals (Farach et al., 2012; Linkievicz et al., 2022). Medications that alter neurotransmitter systems in the brain to address mental health conditions such as depression (Johansen et al., 2023), anxiety (Farach et al., 2012), or schizophrenia (Abbas & Lieberman, 2015).

In essence, the NSBIs harness the latest research and technological advancements to develop methods that can directly impact brain activity, leading to improved mental health, cognitive functioning, and overall quality of life.

4. APPLICATIONS OF NSBIS ON BFP TRAITS

For individuals, who experience stress, anxiety and depression or what is known as SAD (Stress-Anxiety-Depression) syndrome (Xie & Wang, 2021), they often manifest the following pattern of BFP traits: significantly low Openness to Experience [O], significantly low Conscientiousness [C], significantly low Extroversion or significantly high Introversion, and significantly low Agreeableness [A], but significantly high Neuroticism [N].

4.1 Interventions for Openness to Experience [O]

To address significantly low (below an individual's mean cut-off score) Openness to Experience [O], which involves enhancing imagination, curiosity, and creativity, we have suggested the following neuroscience-based intervention strategies to target the brain's default mode network (DMN) and related cognitive functions:

i. Enhancing DMN activity

(a) Creative Exercises (see Răban-Motounu, 2015): Engage in activities designed to stimulate creativity and imaginative thinking. This can include brainstorming sessions, free writing, or engaging in artistic endeavors like painting or music. These activities can activate and strengthen the DMN.

(b) Mindfulness and meditation (see Marlatt & Kristellar, 1999): Practices such as mindfulness meditation can increase activity in the mPFC and other DMN areas by fostering introspection and self-reflection. Techniques like open-monitoring meditation encourage a non-judgmental awareness of thoughts, which can enhance imaginative and abstract thinking.

ii. Cognitive and neuroplasticity-based training

(a) Neuroplasticity exercises (see Huang, Lane, & Lin, 2017): Engage in exercises that challenge your cognitive flexibility, such as problem-solving tasks or learning new skills. For example, learning a new language or musical instrument can enhance neural connectivity in the DMN and other related areas.

(b) Imagination and visualization training (see Xie & Deng, 2023): Practice exercises that involve vivid mental imagery and creative visualization. Techniques like guided imagery or imaginative storytelling can enhance DMN connectivity and stimulate creativity.

iii. Exposure to novel experiences

(a) Novelty exposure (see Huang et al., 2018): Actively seek out new experiences and environments. Traveling, trying new hobbies, or exploring different cultures can provide novel stimuli that engage and expand the DMN.

(b) Curiosity-driven learning (see Sun, 2023): Cultivate curiosity by exploring topics or subjects that are unfamiliar. Engage in activities that require learning and adaptation, such as attending lectures or engaging with diverse forms of media.

iv. Behavioral and contextual strategies

(a) Creativity-fostering environments (see Cropley, 1990): Create environments that are conducive to creative thinking. This might include having a designated space for brainstorming or creative work and surrounding yourself with diverse stimuli.

(b) Social and collaborative creativity (Dingle et al., 2021): Participate in group activities or collaborative projects that require creative problem-solving. Social interactions with diverse and imaginative individuals can stimulate your own creativity.

v. Neurofeedback and cognitive enhancement

(a) Neurofeedback training (see Monderer, Harrison, & Haut, 2002; Wang & Hsieh, 2013; to be conducted by professionals trained in psychophysiology and neurofeedback): Consider neurofeedback interventions that target increased activity in the DMN. Neurofeedback (Hammond, 2007; Niv, 2013) can help you train your brain to achieve states associated with higher creativity and openness.

(b) Cognitive enhancement tools (see Cho et al., 2015): Explore tools and apps designed to enhance cognitive flexibility and creativity. These might include creative problem-solving games or apps that challenge one’s thinking patterns.

vi. Pharmacological and nutritional support

(a) Nutritional supplements (see Granero, 2022, and Manosso, Moretti, & Rodrigues, 2013; under professional guidance of a registered nutritionist): Certain nutrients, like omega-3 fatty acids and antioxidants, support brain health and cognitive function. Ensuring a balanced diet rich in these nutrients can support overall brain activity, including the DMN.

(b) Psychotropic substances (see Ernst & Goldberg, 2004; Pratt et al., 1996; with caution; under professional guidance of a registered psychiatrist or pharmacist): In some contexts, substances like psychedelics have been shown to increase creativity and openness by enhancing DMN connectivity. However, these should only be considered under strict medical supervision due to potential risks and legal issues.

By combining these strategies, you can potentially enhance Openness to Experience by fostering greater creativity, curiosity, and imaginative thinking, ultimately stimulating the DMN and its associated functions.

4.2 Interventions for Conscientiousness [C]

To address significantly low (below an individual's mean cut-off score) Conscientiousness [C], which involves enhancing self-discipline, organization, and goal-directed behavior, the following neuroscience-based strategies to target the prefrontal cortex (PFC) and its associated functions are as follows:

i. Cognitive training

(a) Executive function training (see Channon & Green, 1999): Engage in tasks specifically designed to improve executive functions. This includes activities that require planning, decision-making, and problem-solving. Exercises like complex puzzles, strategy games (e.g., chess), and cognitive tasks that challenge working memory and cognitive flexibility can stimulate the dorsolateral prefrontal cortex (DLPFC).

(b) Working memory training (see Beloe & Derakshan, 2020): Working memory exercises can enhance cognitive control and organization. Programs like Dual N-Back (Lilienthal et al., 2013), which improve the ability to hold and manipulate information, can strengthen the DLPFC and improve self-discipline.

ii. Behavioral interventions

(a) Structured goal setting (see Jacob et al., 2022): Implement structured and systematic goal-setting strategies. Use the SMART criteria (Specific, Measurable, Achievable, Relevant, Time-bound) to set and monitor goals. Regularly review and adjust goals to improve planning and organizational skills.

(b) Time management techniques (see Fatima & Malik, 2019): Use tools and strategies for effective time management. This can include prioritization frameworks, scheduling apps, and techniques like the Pomodoro Technique (Almalki, Alharbi, Al-Ahmadi, & Aljohani, 2020) to enhance focus and productivity.

iii. Neuroscience-based techniques

(a) Mindfulness and meditation (see Marlatt & Kristellar, 1999): Practices such as mindfulness and executive function-focused meditation can enhance self-regulation and cognitive control. Techniques like focused attention meditation and mindfulness-based stress reduction (MBSR) can improve impulse control and planning by increasing activity in the DLPFC.

(b) Neurofeedback training (see Monderer, Harrison, & Haut, 2002; Wang & Hsieh, 2013; to be conducted by professionals trained in psychophysiology and neurofeedback): Neurofeedback involves monitoring and training brain activity to enhance specific cognitive functions (Hammond, 2007). Training to increase beta waves or reduce theta waves, which are associated with attention and executive functions, can improve self-discipline and organization (Niv, 2013; Wang & Hsieh, 213).

iv. Environmental and contextual adjustments

(a) Organized environment (see Barnett et al., 2018): Create a structured and organized environment that supports goal-directed behavior. This can include organizing your workspace, using planners or digital tools for scheduling, and minimizing distractions.

(b) Accountability systems (see Frank & Shim, 2023): Implement systems of accountability, such as regular check-ins with a mentor or using accountability apps. Social support and accountability can reinforce goal-setting and adherence to plans.

v. Cognitive and lifestyle enhancements

(a) Physical exercise (see Carek, Laibstain, & Carek, 2011): Regular physical exercise has been shown to improve executive functions and prefrontal cortex activity. Activities like aerobic exercise, strength training, and sports can enhance cognitive control and self-discipline.

(b) Healthy lifestyle choices (see Sarris et al., 2014; under professional guidance of a qualified dietitian): Maintain a balanced diet, adequate sleep, and stress management practices. Proper nutrition and sleep support overall brain health and cognitive functions, including those related to Conscientiousness [C].

vi. Pharmacological and supplementary support

(a) Cognitive enhancers (see Sachdeva, Kumar, & Anand, 2015; under professional guidance of a registered pharmacist or psychiatrist): In some cases, cognitive enhancers or nootropics, such as modafinil, may be used under medical supervision to improve cognitive control and executive functions. However, this should be approached with caution and professional guidance.

(b) Nutritional supplements (see Granero, 2022, and Manosso, Moretti, & Rodrigues, 2013; under professional guidance of a registered nutritionist): Consider supplements that support brain health and cognitive function, such as omega-3 fatty acids, B vitamins, and antioxidants. These can help maintain optimal brain function and support executive processes.

By combining these neuroscience-based interventions with behavioral strategies, an individual can potentially enhance Conscientiousness [C] by improving self-discipline, organization, and goal-directed behavior, thus stimulating the DLPFC and related cognitive functions.

4.3 Interventions for Extroversion [E] (or Introversion [I])

To address significantly low Extroversion [E] (or significantly high Introversion [I]), you can employ strategies designed to stimulate the brain's reward system, particularly the nucleus accumbens and orbitofrontal cortex (OFC) (Lei, Yang, & Wu, 2015; Mobbs et al., 2005). These interventions aim to enhance sociability, positive emotions, and reward-seeking behavior. Below are some suggested neuroscience-based strategies as follows:

i. Stimulating the reward system

(a) Engage in rewarding activities (see Solomonov et al., 2019): Regularly participate in activities that provide immediate rewards and pleasure. This can include hobbies, social activities, or new experiences that stimulate the nucleus accumbens and OFC. Activities that one can find enjoyable or fulfilling can help increase the activity in these reward-related regions.

(b) Novel experiences (see Marwaha et al., 2023): Introduce new and stimulating experiences into one’s routine. Trying new things, whether it is a new hobby, exploring different places, or learning new skills, can activate the reward system and enhance positive emotions.

ii. Behavioral activation

(a) Gradual social exposure (see de Jong et al., 2023): Start with small social interactions and gradually increase the complexity and duration of these interactions. This can help build confidence and reduce anxiety associated with social situations, leading to more positive reinforcement from these experiences.

(b) Set social goals (see Street, 2002): Create specific, achievable goals related to social interactions. For example, aim to attend a certain number of social events per month or engage in conversations with new people. Use rewards and positive reinforcement to encourage meeting these goals.

iii. Neuroscience-based techniques

(a) Mindfulness and positive visualization (see Wang et al., 2021): Practice mindfulness meditation to improve emotional regulation and reduce anxiety. Positive visualization techniques, where you imagine successful social interactions and positive outcomes, can enhance the reward-related brain regions and boost confidence in social situations.

(b) Neurofeedback training (see Monderer, Harrison, & Haut, 2002; Wang & Hsieh, 2013)to be conducted by professionals trained in psychophysiology and neurofeedback): Consider neurofeedback, which can train one's brain to enhance activity in the reward centers (see Hammond, 2007, for detail). By providing real-time feedback on brain activity, neurofeedback can help a person increase activity in the nucleus accumbens and OFC, potentially improving sociability and reward responsiveness (Niv, 2013).

iv. Emotional and cognitive interventions

(a) Cognitive behavioral therapy (CBT) (see Hollon, Stewart, & Strunk, 2006)under professional guidance of a registered counselor): CBT can help address negative thought patterns related to social interactions and replace them with more positive, constructive beliefs (Wenzel, 2017). This can help improve confidence and increase engagement in social activities.

(b) Gratitude practices (see Cregg & Cheavens, 2021): Engage in daily gratitude practices (Kong et al., 2020), such as writing down things one is grateful for. This can enhance a person's overall mood and activate the reward system by focusing on positive aspects of life and social interactions.

v. Environmental and social adjustments

(a) Create an engaging environment (see Wang et al., 2022): Surround oneself with stimulating and supportive environments that encourage social interaction and exploration. This might include joining clubs, attending events, or creating opportunities for social engagement.

(b) Social support (see Brown & Andrews, 1986): Build a network of supportive friends and family who can encourage and participate in social activities with the person concerned. Having a support system can make social interactions more enjoyable and less stressful.

vi. Physical health and wellness

(a) Regular physical exercise (see Carek, Laibstain, & Carek, 2011): Exercise has been shown to enhance mood and stimulate reward-related brain regions. Activities such as aerobic exercise, yoga, or sports can improve overall brain function and increase positive emotions.

(b) Balanced diet and sleep (see Zhao et al., 2020; under professional guidance of a registered dietitian): Maintain a healthy diet and ensure adequate sleep. Both factors support optimal brain function and can influence mood and energy levels, which are important for engaging in social activities.

vii. Pharmacological and supplementary support

(a) Nutritional supplements (see Granero, 2022, and Manosso, Moretti, & Rodrigues, 2013; under professional guidance of a registered nutritionist): Consider supplements like omega-3 fatty acids, which support brain health and can improve mood and cognitive function. Consult with a healthcare provider before starting any new supplements.

(b) Medication (see Farach et al., 2012; under professional guidance of a registered medical practitioner): In some cases, medications that improve mood or reduce anxiety may be considered.

This should be done under the supervision of a healthcare professional to address underlying issues affecting social engagement.

By incorporating these strategies, an individual can work towards enhancing Extroversion [E] by stimulating the reward system and improving sociability, positive emotions, and engagement in rewarding experiences.

4.4 Interventions for Agreeableness [A]

To address significantly low Agreeableness [A], which involves improving empathy, cooperation, and social harmony, an individual can employ strategies that target the brain regions associated with these traits: the superior temporal sulcus (STS), temporoparietal junction (TPJ), and ventromedial prefrontal cortex (vmPFC) (Owen et al., 2019). Below are some of our suggested neuroscience-based intervention strategies to enhance Agreeableness [A]:

i. Empathy and perspective-taking training

(a) Empathy training (see Silverstone et al., 2015; readers are advised to consult a qualified counselor): Participate in structured empathy training programs that focus on understanding and sharing the feelings of others. Techniques include role-playing exercises, empathy exercises (such as imagining oneself in another person's situation), and reflective listening practices.

(b) Perspective-taking exercises (see Travers-Hill et al., 2017; Yu, Norton, & McCracken, 2017): Engage in activities that encourage you to see things from others' viewpoints. This can involve reading diverse perspectives in literature, engaging in discussions about different viewpoints, or practicing active listening in conversations.

ii. Neuroscience-based techniques

(a) Mindfulness meditation (see Marlatt & Kristellar, 1999): Practice mindfulness meditation to enhance self-awareness and emotional regulation. Mindfulness can improve connectivity in the vmPFC and help regulate emotional responses, which can contribute to better social decision-making and empathy.

(b) Compassion meditation (see Marlatt & Kristellar, 1999): Engage in compassion-focused meditation, such as loving-kindness meditation (LKM). This practice involves sending positive thoughts and wishes to oneself and others, which can enhance activity in the STS, TPJ, and vmPFC, fostering empathy and prosocial behaviors.

iii. Behavioral and social interventions

(a) Social skills training (see Reed, 1994; under professional guidance of a registered educational therapist): Participate in social skills training programs that focus on improving communication, cooperation, and conflict resolution. These programs can enhance your ability to interact harmoniously with others and improve interpersonal skills.

(b) Volunteering and community service (see Ballard et al., 2021): Engage in activities that involve helping others or participating in community service. Volunteering can provide practical experience in empathizing with others and working cooperatively in social settings.

iv. Cognitive and Emotional Strategies

(a) Moral reasoning exercises (see Martin, 1999): Practice exercises that involve ethical and moral reasoning. Engage in discussions or activities that require a person to consider the moral implications of various actions, which can stimulate the vmPFC and enhance social decision-making.

(b) Gratitude practices (see Cregg & Cheavens, 2021): Implement daily gratitude practices to focus on positive social interactions and relationships. Keeping a gratitude journal and reflecting on positive social experiences can improve overall social harmony and interpersonal connections (Kong et al., 2020).

v. Neurofeedback and cognitive training

(a) Neurofeedback training (see Monderer, Harrison, & Haut, 2002; Wang & Hsieh, 2013; to be conducted by professionals trained in psychophysiology and neurofeedback): Consider neurofeedback interventions aimed at increasing activity in the vmPFC, STS, and TPJ. Neurofeedback can help you regulate brain activity to enhance empathy and social decision-making (Hammond, 2007; Niv, 2013).

(b) Cognitive training programs (see Wolinsky et al., 2009; e.g., Fast ForWord and NeuroLat): Use cognitive training programs (Chia & Ng, 2021) that target social cognition and emotional intelligence. These programs can include tasks designed to improve perspective-taking, empathy, and moral reasoning.

vi. Environmental and contextual adjustments

(a) Supportive social environments (see Glover, 1998): Create or seek out environments that foster social harmony and cooperation. Surround oneself with individuals who model prosocial behavior and engage in activities that encourage positive social interactions.

(b) Feedback and reflection (see Aguilera & Berridge, 2014): Regularly seek feedback from others about one's social interactions and reflect on how one can improve. Engaging in self-reflection and considering others' perspectives can help develop greater empathy and agreeableness.

vii. Pharmacological and nutritional support

(a) Nutritional supplements (see Granero, 2022, and Manosso, Moretti, & Rodrigues, 2013; under professional guidance of a registered nutritionist: Consider supplements that support brain health and emotional well-being, such as omega-3 fatty acids, which have been shown to influence mood and social behavior. Consult with a healthcare provider before starting any new supplements.

(b) Medication (see Farach et al., 2012; under professional guidance of a registered psychiatrist or pharmacologist): In some cases, medication that addresses mood or emotional regulation might be considered. This should be done under the supervision of a healthcare professional, especially if there are underlying conditions affecting social behavior.

By integrating these neuroscience-based interventions with behavioral and cognitive strategies, an individual can work towards enhancing Agreeableness [A] by improving empathy, cooperation, and social harmony. This approach targets the relevant brain regions and functions to foster more prosocial behaviors and interpersonal connections.

4.5 Interventions for Neuroticism [N]

To address significantly high Neuroticism [N], characterized by emotional instability and anxiety, you can employ strategies that target the brain regions involved—namely the amygdala, hippocampus, and anterior cingulate cortex (ACC). These strategies aim to reduce emotional reactivity, improve emotion regulation, and manage stress. Below are some suggested neuroscience-based intervention strategies:

i. Neuroscience-based techniques

(a) Mindfulness meditation (see Marlatt & Kristellar, 1999): Mindfulness practices can help regulate activity in the amygdala and ACC. Regular mindfulness meditation reduces emotional reactivity and stress by enhancing the brain's ability to process emotions more calmly. Techniques include focused attention, body scan, and loving-kindness meditation.

(b) Cognitive behavioral therapy (CBT) (see Hollon, Stewart, & Strunk, 2006); readers are advised to consult a qualified counselor qualified in CBT): CBT helps modify negative thought patterns and behaviors that contribute to anxiety and emotional instability (Wenzel, 2017). By addressing cognitive distortions and teaching coping strategies, CBT can reduce amygdala reactivity and improve emotion regulation through the ACC.

(c) Neurofeedback training (see Monderer, Harrison, & Haut, 2002, and Wang & Hsieh, 2013; to be conducted by professionals trained in psychophysiology and neurofeedback): Neurofeedback can train individuals to regulate brain activity in areas like the amygdala and ACC. For example, neurofeedback training aimed at increasing alpha and beta wave activity can improve emotional stability and stress management (Hammond, 2007; Niv, 2013).

ii. Emotional regulation and stress management

(a) Emotion regulation skills (see Compare et al., 2014; readers are advised to consult a qualified counselor): Develop skills to manage and regulate emotions more effectively. Techniques include deep breathing exercises, progressive muscle relaxation, and visualization exercises. These practices help modulate amygdala activity and reduce stress responses.

(b) Stress management techniques (see Yazdani, Rezaei, & Pahlavanzadeh, 2010): Implement strategies to manage stress, such as time management, relaxation techniques, and physical exercise. Stress reduction can lower hippocampal reactivity and improve overall emotional stability.

iii. Cognitive and behavioral interventions

(a) Exposure therapy (see Caraske et al., 2014): Gradual exposure to anxiety-provoking situations can help desensitize the amygdala’s response to fear. This technique involves systematic and controlled exposure to stressors to reduce anxiety over time (Craske et al., 2014).

(b) Positive psychology practices (see Chaves et al., 2017; readers are advised to consult a qualified counselor): Engage in positive psychology interventions, such as gratitude exercises (Cregg & Cheavens, 2021); Kong et al., 2020) and optimism training (Riskind, Sarampote, & Mercier, 1996). These practices can shift focus away from negative emotions and reduce the impact of Neuroticism [N] by enhancing overall mood and resilience.

iv. Neuroplasticity-based training

(a) Cognitive training (see Cho et al., 2015): Engage in cognitive training programs (Chia & Ng, 2021) that focus on enhancing executive functions and emotional regulation. Tasks that improve cognitive flexibility and resilience can help modulate the activity of the ACC and hippocampus.

(b) Emotional intelligence (EQ) training (see Slaski & Cartwright, 2003; readers are advised to consult a qualified counselor or psychotherapist): Develop emotional intelligence skills, including empathy, self-awareness, and self-regulation. The EQ training in these areas can improve emotion management and reduce the intensity of negative emotional responses (Slaski & Cartwright, 2003).

v. Lifestyle and environmental adjustments

(a) Regular physical exercise (see Carek, Laibstain, & Carek, 2011): Exercise has been shown to reduce stress and anxiety while enhancing mood. Activities like aerobic exercise, yoga, and strength training can help lower amygdala reactivity and improve emotional regulation.

(b) Healthy sleep and nutrition (see Zhao et al., 2020; readers are advised to consult a qualified nutritionist): Maintain a balanced diet and ensure adequate sleep (Granero, 2022). Both factors support overall brain health and can help manage stress and emotional stability. Practices such as sleep hygiene and a diet rich in omega-3 fatty acids can support mental health.

vi. Pharmacological and supplementary support

(a) Pharmacological interventions (see Farach et al., 2012; under professional guidance of a registered pharmacologist): In some cases, medications such as selective serotonin reuptake inhibitors (SSRIs) or anxiolytics might be prescribed to help manage symptoms of anxiety and emotional instability. This should be done under the supervision of a healthcare professional.

(b) Nutritional supplements (see Granero, 2022, and Manosso, Moretti, & Rodrigues, 2013; readers are advised to consult a qualified nutritionist): Consider supplements that support brain health and emotional well-being, such as omega-3 fatty acids, magnesium, or B vitamins. Consult with a healthcare provider before starting any new supplements to ensure they are appropriate for your needs.

vii. Social and supportive interventions

(a) Social support (see Brown & Andrews, 1986): Build a strong support network of friends, family, and mental health professionals. Social support can provide emotional comfort and practical assistance, helping to buffer the effects of high Neuroticism [N].

(b) Therapeutic alliance or relationships (see Cameron, Rodgers, & Dagnan, 2018); readers are advised to consult a qualified counselor): Engage in therapy or counseling with professionals who can offer support and guidance. Therapeutic alliance/relationships can help you develop coping strategies, gain insights into emotional patterns, and improve emotional regulation.

By integrating these neuroscience-based strategies with cognitive and behavioral approaches, an individual can work towards reducing high Neuroticism [N], improving emotional stability, and enhancing overall well-being. These interventions target the relevant brain regions involved in emotional processing and stress responses to foster a more balanced emotional state.

5. A CASE STUDY

A single mother, who has to manage two young adults diagnosed with autism spectrum disorder (ASD) and intellectual and developmental disabilities (IDD) when they were younger, has assessed on the Big Five Inventory (BFI) to obtain the following BFI profile: low on Openness to Experience [O], Conscientiousness [C], Extroversion [E], and Agreeableness [A], but high on Neuroticism [N]. In this hypothetical case, she may exhibit certain psychological and behavioral tendencies that can have implications for her mental health as explained below:

1. Low Openness to Experience [O]: This suggests the mother may be more conventional, less open to new experiences, and resistant to change. She might prefer routine and familiarity over novelty and variety.

2. Low Conscientiousness [C]: This indicates a tendency toward disorganization, lack of dependability, and a lower degree of self-discipline. She might struggle with goal-directed behaviors and might be perceived as unreliable.

3. Low Extroversion [E]: This suggests that the mother is more introverted, may be reserved, and might prefer solitary activities over social interactions. She might find social situations draining and may not seek out social stimulation.

4. Low Agreeableness [A]: This suggests her tendency towards being less cooperative, more competitive, and potentially more antagonistic. The woman might have difficulty getting along with others and may come across as skeptical or less trusting.

5. High Neuroticism [N]: This is associated with a higher tendency towards experiencing negative emotions such as anxiety, sadness, and irritability. Having scored high in Neuroticism [N], the woman is more prone to emotional instability and stress.

Given this profile, the single mother might be at an increased risk for stress (S), anxiety (A), and depression (D), which is also identified and known as SAD Syndrome (Xie & Wang, 2021). High Neuroticism [N] is particularly associated with a higher likelihood of experiencing emotional disturbances and mood disorders. The combination of low Conscientiousness [C] and high Neuroticism [N] can lead to difficulties in managing daily stressors effectively, potentially exacerbating feelings of anxiety and depression (Jylhä & Isometsä, 2006; Uliaszek et al., 2009).

The low scores in Extraversion [E] and Agreeableness [A] could mean the single mother may not have strong social support networks, which are often crucial in coping with stress and emotional disturbances. Additionally, low Openness to Experiennce [O] could make it difficult for this woman to adapt to new coping strategies or seek new experiences that might help alleviate her distress.

In the brief overall, this BFI profile suggests a potential for emotional and psychological challenges, including anxiety and depression, and it might be beneficial for an individual such as this single mother in the hypothetical case to seek support from mental health professionals to develop coping strategies and interventions tailored to her specific personality traits.

5.1 From the Perspective of Neuroscience

From the neuroscience perspective, the single mother's mental wellness might be impacted in the following ways based on her BFPTs profile:

1. Low Openness: This trait is associated with reduced activity in brain regions involved in novelty seeking and flexibility, such as the prefrontal cortex (PFC). A lower openness could limit her ability to adapt to new coping mechanisms or stressors, potentially reinforcing neural pathways that resist change and increase rigidity.

2. Low Conscientiousness: This trait relates to diminished function in areas of the brain responsible for executive functions, like the dorsolateral prefrontal cortex (dlPFC). This could result in difficulties with organization, self-discipline, and goal-directed behaviors, exacerbating stress management challenges and potentially impacting her overall mental health.

3. Low Extroversion: Lower levels of extroversion may correlate with reduced activation in brain regions involved in reward processing and social engagement, such as the ventral striatum and orbitofrontal cortex (OFC). This could lead to decreased social interactions and reduced social support, contributing to feelings of isolation and diminished coping resources.

4. Low Agreeableness: This trait may involve reduced connectivity in brain networks related to empathy and social cooperation, like the temporoparietal junction (TPJ) and anterior cingulate cortex (ACC). A lower agreeableness might hinder her ability to form supportive relationships, potentially increasing interpersonal conflicts and stress.

5. High Neuroticism: High neuroticism is linked to heightened activity in brain regions associated with emotional reactivity, such as the amygdala and the anterior cingulate cortex (ACC). This increased

emotional sensitivity can lead to higher levels of anxiety, stress, and depressive symptoms, as these brain areas may become overactive in response to perceived threats or stressors.

6. CONCLUSION

In summary, the combination of these traits (Figure 1) suggests a higher likelihood of experiencing emotional instability, stress, and difficulties in managing daily challenges. The neural underpinnings of her personality profile indicate a potential for heightened vulnerability to mental health issues such as anxiety and depression. Seeking support from mental health professionals to develop personalized coping strategies and interventions could be beneficial in addressing these challenges and enhancing her overall well-being.

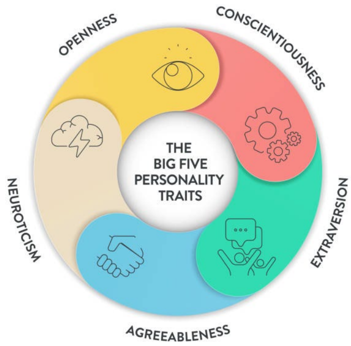

Figure 1. Big Five Personality Traits

7. ACKNOWLEDGEMENT

None.

8. COMPETING INTERESTS

Authors have declared that no competing interests exist.

9. FINANCIAL DISCLOSURE

Non funds obtained.

10. ARTIFICIAL INTELLIGENCE DISCLOSURE

No generative AI or AI-assisted technologies were used in the preparation of this manuscript.

REFERENCES

Abbas, A. I., & Lieberman, J. A. (2015). Pharmacological treatments for schizophrenia. In P. E. Nathan & J. M. Gorman (Eds.), *A guide to treatments that work* (4th ed.) (pp. 175-215). New York, NY: Oxford Academic. https://doi.org/10.1093/med:psych/9780199342211.003.0006

Aguilera, A., & Berridge, C. (2014). Qualitative feedback from a text messaging intervention for depression: benefits, drawbacks, and cultural differences. *Journal of Medical Internet Research in Mobile Health (mHealth) and Ubiquitous Health (uHealth) [JMIR mHealth & uHealth]*, *2*(4). Article ID: e3660. https://doi.org/10.2196/mhealth.3660

Almalki, K., Alharbi, O., Al-Ahmadi, W. A., & Aljohani, M. (2020). Anti-procrastination online tool for graduate students based on the pomodoro technique. In *Learning and Collaboration Technologies. Human and Technology Ecosystems: 7th International Conference, LCT 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings, Part II 22* (pp. 133-144). Springer International Publishing. https://doi.org/10.1007/978-3-030-50506-6_10

Ballard, P. J., Daniel, S. S., Anderson, G., Nicolotti, L., Caballero Quinones, E., Lee, M., & Koehler, A. N. (2021). Incorporating volunteering into treatment for depression among adolescents: Developmental and clinical considerations. *Frontiers in Psychology*, *12*. Article ID: 642910. https://doi.org/10.3389/fpsyg.2021.642910

Blain, S. D., Grazioplene, R. G., Ma, Y., & DeYoung, C. G. (2020). Toward a neural model of the Openness-Psychoticism dimension: Functional connectivity in the default and frontoparietal control networks. *Schizophrenia Bulletin*, *46*(3), 540-551. https://doi.org/10.1093/schbul/sbz103

Barnett, A., Zhang, C. J., Johnston, J. M., & Cerin, E. (2018). Relationships between the neighborhood environment and depression in older adults: A systematic review and meta-analysis. *International Psychogeriatrics*, *30*(8), 1153-1176. https://doi.org/10.1017/S104161021700271X

Beloe, P., & Derakshan, N. (2020). Adaptive working memory training can reduce anxiety and depression vulnerability in adolescents. *Developmental Science*, *23*(4). Article ID: e12831. https://doi.org/10.1111/desc.12831

Borton, D., Micera, S., Millán, J. D. R., & Courtine, G. (2013). Personalized neuroprosthetics. *Science Translational Medicine*, *5*(210), 210rv2-210rv2. https://doi.org/10.1126/scitranslmed.3005968

Brown, G.W., Andrews, B. (1986). Social support and depression. In M. H. Appley & R. Trumbull, R. (Eds.), Dynamics of stress. The Plenum series on stress and coping (pp. 257-282). Boston, MA: Springer. https://doi.org/10.1007/978-1-4684-5122-1_13

Cameron, S. K., Rodgers, J., & Dagnan, D. (2018). The relationship between the therapeutic alliance and clinical outcomes in cognitive behaviour therapy for adults with depression: A meta-analytic review. *Clinical Psychology & Psychotherapy*, *25*(3), 446-456. https://doi.org/10.1002/cpp.2180

Carek, P. J., Laibstain, S. E., & Carek, S. M. (2011). Exercise for the treatment of depression and anxiety. *The International Journal of Psychiatry in Medicine*, *41*(1), 15-28. https://doi.org/10.2190/PM.41.1.c

Casillo, S. M., Luy, D. D., & Goldschmidt, E. (2020). A history of the lobes of the brain. *World neurosurgery*, *134*, 353-360. https://doi.org/10.1016/j.wneu.2019.10.155

Channon, S., & Green, P. S. S. (1999). Executive function in depression: The role of performance strategies in aiding depressed and non-depressed participants. *Journal of Neurology, Neurosurgery & Psychiatry*, *66*(2), 162-171. https://doi.org/10.1136/jnnp.66.2.162

Chaves, C., Lopez-Gomez, I., Hervas, G., & Vazquez, C. (2017). A comparative study on the efficacy of a positive psychology intervention and a cognitive behavioral therapy for clinical depression. *Cognitive Therapy and Research*, *41*, 417-433. https://doi.org/10.1007/s10608-016-9778-9

Chia, N. K. H., & Ng, M. L. (2021, Summer). Cognition, cognitive abilities and cognitive training program. *Unlimited Human!* 4-6.

Cho, M., Kim, D., Chung, J., Park, J., You, H., & Yang, Y. (2015). Effects of a cognitive-enhancement group training program on daily living activities, cognition, and depression in the demented elderly. *Journal of Physical Therapy Science*, *27*(3), 681-684. https://doi.org/10.1589/jpts.29.744

Compare, A., Zarbo, C., Shonin, E., Van Gordon, W., & Marconi, C. (2014). Emotional regulation and depression: A potential mediator between heart and mind. *Cardiovascular psychiatry and neurology*, *2014*(1). Article ID: 324374. https://doi.org/10.1155/2014/324374

Craske, M. G., Treanor, M., Conway, C. C., Zbozinek, T., & Vervliet, B. (2014). Maximizing exposure therapy: An inhibitory learning approach. *Behaviour Research and Therapy*, *58*, 10-23. https://doi.org/10.1016/j.brat.2014.04.006

Cregg, D. R., & Cheavens, J. S. (2021). Gratitude interventions: Effective self-help? A meta-analysis of the impact on symptoms of depression and anxiety. *Journal of Happiness Studies*, *22*(1), 413-445. https://doi.org/10.1007/s10902-020-00236-6

Cropley, A. J. (1990). Creativity and mental health in everyday life. *Creativity Research Journal*, *3*(3), 167-178. https://doi.org/10.1080/10400419009534351

de Jong, R., Hofs, A., Lommen, M. J., van Hout, W. J., De Jong, P. J., & Nauta, M. H. (2023). Treating specific phobia in youth: A randomized controlled microtrial comparing gradual exposure in large steps to exposure in small steps. *Journal of Anxiety Aisorders*, *96*. Article ID: 102712. https://doi.org/10.1016/j.janxdis.2023.102712

Dingle, G. A., Sharman, L. S., Haslam, C., Donald, M., Turner, C., Partanen, R., ... & van Driel, M. L. (2021). The effects of social group interventions for depression: Systematic review. *Journal of Affective Disorders*, *281*, 67-81. https://doi.org/10.1016/j.jad.2020.11.125

Ernst, C. L., & Goldberg, J. F. (2004). Anti-suicide properties of psychotropic drugs: A critical review. *Harvard Review of Psychiatry*, *12*(1), 14-41. https://doi.org/10.1080/714858480

Farach, F. J., Pruitt, L. D., Jun, J. J., Jerud, A. B., Zoellner, L. A., & Roy-Byrne, P. P. (2012). Pharmacological treatment of anxiety disorders: Current treatments and future directions. *Journal of Anxiety Disorders*, *26*(8), 833-843. https://doi.org/10.1016/j.janxdis.2012.07.009

Fatima, I., & Malik, S. (2019). Effects of supervisor support on depression symptoms in research students: Time management as moderator. *Journal of Behavioural Sciences*, *29*(1), 1-12.

Faustino, B. (2022). Minding my brain: Fourteen neuroscience-based principles to enhance psychotherapy responsiveness. *Clinical Psychology & Psychotherapy*, *29*(4), 1254-1275. https://doi.org/10.1002/cpp.2719

Forbes, C. E., Poore, J. C., Krueger, F., Barbey, A. K., Solomon, J., & Grafman, J. (2014). The role of executive function and the dorsolateral prefrontal cortex in the expression of neuroticism and conscientiousness. *Social Neuroscience*, *9*(2), 139-151. https://doi.org/10.1080/17470919.2013.871333

Frank, R. G., & Shim, R. S. (2023). Toward greater accountability in mental health care. *Psychiatric Services*, *74*(2), 182-187. https://doi.org/10.1176/appi.ps.20220097

Genevsky, A., Garrett, C. T., Alexander, P. P., & Vinogradov, S. (2010). Cognitive training in schizophrenia: A neuroscience-based approach. *Dialogues in Clinical Neuroscience*, *12*(3), 416-421. https://doi.org/10.31887/DCNS.2010.12.3/agenevsky

Glover, S. A. O. (1998). Social environments and the emotional well-being of young people. *Family Matters*, (49), 11-16.

Granero R. (2022). Role of Nutrition and Diet on Healthy Mental State. *Nutrients*, *14*(4). Article No. 750. https://doi.org/10.3390/nu14040750

Haas, B. W., Omura, K., Constable, R. T., & Canli, T. (2007). Emotional conflict and neuroticism: personality-dependent activation in the amygdala and subgenual anterior cingulate. *Behavioral neuroscience*, *121*(2), 249–256. https://doi.org/10.1037/0735-7044.121.2.249

Hammond, D. C. (2005). Neurofeedback treatment of depression and anxiety. *Journal of Adult Development*, *12*, 131-137. https://doi.org/10.1007/s10804-005-7029-5

Hammond, D. C. (2007). What is neurofeedback? *Journal of Neurotherapy*, *10*(4), 25-36. https://doi.org/10.1300/J184v10n04_04

Hibberd, J., & Usmar, J. (2015). *This book will make you mindful*. London, UK: Quercus Editions.

Hollon, S. D., Stewart, M. O., & Strunk, D. (2006). Enduring effects for cognitive behavior therapy (CBT) in the treatment of depression and anxiety. *Annual Review of Psychology*, *57*(1), 285-315. https://doi.org/10.1146/annurev.psych.57.102904.190044

Huang, F., Tang, S., Sun, P., & Luo, J. (2018). Neural correlates of novelty and appropriateness processing in externally induced constraint relaxation. *NeuroImage*, *172*, 381-389. https://doi.org/10.1016/j.neuroimage.2018.01.070

Huang, Y. J., Lane, H. Y., & Lin, C. H. (2017). New treatment strategies of depression: based on mechanisms related to neuroplasticity. *Neural Plasticity*, *2017*(1). Article ID: 4605971. https://doi.org/10.1155/2017/4605971

Huo, T., Li, Y., Zhuang, K., Song, L., Wang, X., Ren, Z., ... & Qiu, J. (2020). Industriousness moderates the link between default mode network subsystem and creativity. *Neuroscience*, *427*, 92-104. https://doi.org/10.1016/j.neuroscience.2019.11.049

Jacob, J., Stankovic, M., Spuerck, I., & Shokraneh, F. (2022). Goal setting with young people for anxiety and depression: What works for whom in therapeutic relationships? A literature review and insight analysis. *BMC Psychology*, *10*(1). Article No. 171. https://doi.org/10.1186/s40359-022-00879-5

Johansen, A., Armand, S., Plavén-Sigray, P., Nasser, A., Ozenne, B., Petersen, I. N., ... & Knudsen, G. M. (2023). Effects of escitalopram on synaptic density in the healthy human brain: A randomized controlled trial. *Molecular Psychiatry*, *28*(10), 4272-4279. https://doi.org/10.1038/s41380-023-02285-8

John, O. P., Donahue, E. M., & Kentle, R. L. (1991). *The Big Five Inventory - Versions 41 and 54*. Berkeley, CA: University of California-Berkeley, Institute of Personality and Social Research. https://doi.org/10.1037/t07550-000

John, O. P., Naumann, L. P., & Soto, C. J. (2008). Paradigm shift to the integrative Big-Five traits taxonomy: History, measurement, and conceptual issues. In O. P. John, R. W. Robins, & L. A. Pervin (Eds.), *Handbook of personality: Theory and research* (pp. 114-158). New York, NY: Guilford Press.

Jun, J., & Yoo, S. (2018). Three research strategies of neuroscience and the future of legal imaging evidence. *Frontiers in Neuroscience*, *12*. Aritcle No. 120. https://doi.org/10.3389/fnins.2018.00120

Jylhä, P., & Isometsä, E. (2006). The relationship of neuroticism and extraversion to symptoms of anxiety and depression in the general population. *Depression and Anxiety*, *23*(5), 281-289. https://doi.org/10.1002/da.20167

Karavidas, M. K., Lehrer, P. M., Vaschillo, E., Vaschillo, B., Marin, H., Buyske, S., ... & Hassett, A. (2007). Preliminary results of an open label study of heart rate variability biofeedback for the treatment of major depression. *Applied Psychophysiology and Biofeedback*, *32*, 19-30. https://doi.org/10.1007/s10484-006-9029-z

Kong, F., Zhao, J., You, X., & Xiang, Y. (2020). Gratitude and the brain: Trait gratitude mediates the association between structural variations in the medial prefrontal cortex and life satisfaction. *Emotion*, *20*(6), 917-926. https://doi.org/10.1037/emo0000617

Lei, X., Yang, T., & Wu, T. (2015). Functional neuroimaging of extraversion-introversion. *Neuroscience Bulletin*, *31*, 663-675. https://doi.org/10.1007/s12264-015-1565-1

Lilienthal, L., Tamez, E., Shelton, J. T., Myerson, J., & Hale, S. (2013). Dual n-back training increases the capacity of the focus of attention. *Psychonomic Bulletin & Review*, *20*, 135-141. https://doi.org/10.3758/s13423-012-0335-6

Linkievicz, N. M., Sgnaolin, V., Engroff, P., Behr Gomes Jardim, G., & Cataldo, A. (2022). Association between Big Five personality factors and medication adherence in the elderly. *Trends in Psychiatry and Psychotherapy*, *44*. Article ID: e20200143. https://doi.org/10.47626/2237-6089-2020-0143

Manosso, L. M., Moretti, M., & Rodrigues, A. L. S. (2013). Nutritional strategies for dealing with depression. *Food & Function*, *4*(12), 1776-1793. https://doi.org/10.1039/C3FO60246J

Marlatt, G. A., & Kristeller, J. L. (1999). Mindfulness and meditation. In W. R. Miller (Ed.), *Integrating spirituality into treatment: Resources for practitioners* (pp. 67–84). Washington, DC: American Psychological Association. https://doi.org/10.1037/10327-004

Martin, M. W. (1999). Depression and moral health: A response to the commentary. *Philosophy, Psychiatry, & Psychology*, *6*(4), 295-298.

Marwaha, S., Palmer, E., Suppes, T., Cons, E., Young, A. H., & Upthegrove, R. (2023). Novel and emerging treatments for major depression. *The Lancet*, *401*(10371), 141-153. https://doi.org/10.1016/S0140-6736(22)02080-3

Mobbs, D., Hagan, C. C., Azim, E., Menon, V., & Reiss, A. L. (2005). Personality predicts activity in reward and emotional regions associated with humor. *Proceedings of the National Academy of*

Sciences of the United States of America, *102*(45), 16502-16506. https://doi.org/10.1073/pnas.0408457102
Monderer, R. S., Harrison, D. M., & Haut, S. R. (2002). Neurofeedback and epilepsy. *Epilepsy & Behavior*, *3*(3), 214-218. https://doi.org/10.1016/s1525-5050(02)00001-x
Niv, S. (2013). Clinical efficacy and potential mechanisms of neurofeedback. *Personality and Individual Differences*, *54*(6), 676-686. https://doi.org/10.1016/j.paid.2012.11.037
O'Brien, J. (2021). Brain fitness for school children: BrainFutures champions neuroscience-based interventions. *Childhood Education*, *97*(1), 42-49. https://doi.org/10.1080/00094056.2021.1873692
Owens, M. M., Hyatt, C. S., Gray, J. C., Carter, N. T., MacKillop, J., Miller, J. D., & Sweet, L. H. (2019). Cortical morphometry of the five-factor model of personality: Findings from the Human Connectome Project full sample. *Social Cognitive and Affective Neuroscience*, *14*(4), 381-395. https://doi.org/10.1093/scan/nsz017
Pessoa, L. (2022). *The entangled brain: How perception, cognition, and emotion are woven together*. Cambridge, MA: MIT Press. https://doi.org/10.7551/mitpress/14636.001.0001
Pratt, L. A., Ford, D. E., Crum, R. M., Armenian, H. K., Gallo, J. J., & Eaton, W. W. (1996). Depression, psychotropic medication, and risk of myocardial infarction: prospective data from the Baltimore ECA follow-up. *Circulation*, *94*(12), 3123-3129. https://doi.org/10.1161/01.CIR.94.12.3123
Răban-Motounu, N. (2015). Creative Techniques In The Psychotherapy of Depression. *Journal of Experiential Psychotherapy/Revista de PSIHOterapie Experientiala*, *18*(2), 28-34.
Rammstedt, B., & John, O.P. (2020). Big Five Inventory. In V. Zeigler-Hill, & T. K. Shackelford (Eds), *Encyclopedia of Personality and Individual Differences* (pp. 469-471). Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-24612-3_445
Reed, M. K. (1994). Social skills training to reduce depression in adolescents. *Adolescence*, *29*(114), 293-302.
Riskind, J. H., Sarampote, C. S., & Mercier, M. A. (1996). For every malady a sovereign cure: Optimism training. *Journal of Cognitive Psychotherapy, 10*(2), 105–117.
Sachdeva, A., Kumar, K., & Anand, K. S. (2015). Non pharmacological cognitive enhancers–current perspectives. *Journal of Clinical and Diagnostic Research: JCDR*, *9*(7), VE01-VE06. https://doi.org/10.7860/JCDR/2015/13392.6186
Sarris, J., O'Neil, A., Coulson, C. E., Schweitzer, I., & Berk, M. (2014). Lifestyle medicine for depression. *BMC Psychiatry*, *14*, 1-13. https://doi.org/10.1186/1471-244X-14-107
Schwartz, M. S., & Andrasik, F. (Eds.). (2017). *Biofeedback: A practitioner's guide*. New York, NY: Guilford Press. https://doi.org/10.1080/07317107.2017.1307683
Silverstone, P. H., Bercov, M., Suen, V. Y., Allen, A., Cribben, I., Goodrick, J., ... & McCabe, C. (2015). Initial findings from a novel school-based program, EMPATHY, which may help reduce depression and suicidality in youth. *PloS One*, *10*(5). Article ID: e0125527. https://doi.org/10.1371/journal.pone.0125527
Slaski, M., & Cartwright, S. (2003). Emotional intelligence training and its implications for stress, health and performance. *Stress and Health*, *19*(4), 233-239. https://doi.org/10.1002/smi.979
Solomonov, N., Bress, J. N., Sirey, J. A., Gunning, F. M., Flückiger, C., Raue, P. J., ... & Alexopoulos, G. S. (2019). Engagement in socially and interpersonally rewarding activities as a predictor of outcome in "Engage" behavioral activation therapy for late-life depression. *The American Journal of Geriatric Psychiatry*, *27*(6), 571-578. https://doi.org/10.1016/j.jagp.2018.12.033
Street, H. (2002). Exploring relationships between goal setting, goal pursuit and depression: A review. *Australian Psychologist*, *37*(2), 95-103. https://doi.org/10.1080/00050060210001706736
Sun, C. (2023). *Curiosity-driven learning in artificial intelligence and its applications*. (Doctoral thesis, Nanyang Technological University, Singapore). [Access: https://hdl.handle.net/10356/172831].
Sun, J., Shi, L., Chen, Q., Yang, W., Wei, D., Zhang, J., ... & Qiu, J. (2019). Openness to experience and psychophysiological interaction patterns during divergent thinking. *Brain Imaging and Behavior*, *13*, 1580-1589. https://doi.org/10.1007/s11682-018-9965-2

Travers-Hill, E., Dunn, B. D., Hoppitt, L., Hitchcock, C., & Dalgleish, T. (2017). Beneficial effects of training in self-distancing and perspective broadening for people with a history of recurrent depression. *Behaviour Research and Therapy*, *95*, 19-28. http://doi.org/10.1016/j.brat.2017.05.008
Tzschoppe, J., Nees, F., Banaschewski, T., Barker, G. J., Büchel, C., Conrod, P. J., ... & Flor, H. (2014). Aversive learning in adolescents: Modulation by amygdala-prefrontal and amygdala-hippocampal connectivity and neuroticism. *Neuropsychopharmacology*, *39*(4), 875-884. https://doi.org/10.1038/npp.2013.287
Uliaszek, A. A., Hauner, K. K., Zinbarg, R. E., Craske, M. G., Mineka, S., Griffith, J. W., & Rose, R. D. (2009). An examination of content overlap and disorder-specific predictions in the associations of neuroticism with anxiety and depression. *Journal of Research in Personality*, *43*(5), 785-794. https://doi.org/10.1016/j.jrp.2009.05.009
van der Knaap, M. S., & Valk, J. (2005). Myelin and white matter. In M. S. van der Knaap & J. Valk (Eds.), *Magnetic resonance of myelination and myelin disorders* (pp. 1-19). Berlin, Germany: Springer. https://doi.org/10.1007/3-540-27660-2
Wang, J. R., & Hsieh, S. (2013). Neurofeedback training improves attention and working memory performance. *Clinical Neurophysiology*, *124*(12), 2406-2420. https://doi.org/10.1016/j.clinph.2013.05.020
Wang, Y., Liao, L., Lin, X., Sun, Y., Wang, N., Wang, J., & Luo, F. (2021). A bibliometric and visualization analysis of mindfulness and meditation research from 1900 to 2021. *International Journal of Environmental Research and Public Health*, *18*(24). Article ID: 13150. https://doi.org/10.3390/ijerph182413150
Wang, Z., Li, Y., An, J., Dong, W., Li, H., Ma, H., ... & Wang, G. (2022). Effects of restorative environment and presence on anxiety and depression based on interactive virtual reality scenarios. *International Journal of Environmental Research and Public Health*, *19*(13). Article ID: 7878. https://doi.org/10.3390/ijerph19137878
Wenzel, A. (2017). Basic strategies of cognitive behavioral therapy. *Psychiatric Clinics*, *40*(4), 597-609. https://doi.org/10.1016/j.psc.2017.07.001
Wolinsky, F. D., Mahncke, H. W., Weg, M. W. V., Martin, R., Unverzagt, F. W., Ball, K. K., ... & Tennstedt, S. L. (2009). The ACTIVE cognitive training interventions and the onset of and recovery from suspected clinical depression. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *64*(5), 577-585. https://doi.org/10.1093/geronb/gbp061
Xie, G. H., & Deng, M. J. (2023). *The spectrum of imagination in autism.* Saarland, Germany: Lambert Academic Publishing.
Xie, G. H., & Wang, Q. (2021). Mandala coloring as a therapeutic tool in treating stress-anxiety-depression (SAD) syndrome. *Asian Journal of Interdisciplinary Research*, *4*(4), 30-36. https://doi.org/10.54392/ajir2144
Yazdani, M., Rezaei, S., & Pahlavanzadeh, S. (2010). The effectiveness of stress management training program on depression, anxiety and stress of the nursing students. *Iranian Journal of Nursing and Midwifery Research*, *15*(4), 208-215.
Yu, L., Norton, S., & McCracken, L. M. (2017). Change in "self-as-context"("perspective-taking") occurs in acceptance and commitment therapy for people with chronic pain and is associated with improved functioning. *The Journal of Pain*, *18*(6), 664-672. https://doi.org/10.1016/j.jpain.2017.01.005
Yucha, C., & Montgomery, D. (2008). *Evidence-based practice in biofeedback and neurofeedback*. Wheat Ridge, CO: Association for Applied Psychophysiology and Biofeedback (AAPB).
Zhao, M., Tuo, H., Wang, S., & Zhao, L. (2020). The effects of dietary nutrition on sleep and sleep disorders. *Mediators of inflammation*, *2020*(1). Article ID: 3142874. https://doi.org/10.1155/2020/3142874