REGULAR

ANATOMY & PHYSIOLOGY

THE TRIPLE NETWORK

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Traditionally, when considering the anatomy and physiology involved in post-traumatic stress disorder (PTSD), literature has tended to focus on specific brain areas, in particular the limbic system and the pre-frontal cortex. Located deep in the brain below the temporal lobes and under the cerebral cortex, the limbic system is made up of two major structures, the amygdala and hippocampus, with others including the hypothalamus, cingulate gyrus, dentate gyrus, parahippocampal gyrus, fornix, and other nuclei and septa (Guy-Evans, 2021; Marieb & Hoehn, 2010). The limbic system is involved in learning, the processing and regulating of emotions, and the formation and storage of memories. It plays an important role in the stress response as it has strong connections to the endocrine system and autonomic nervous system (Guy-Evans, 2021).

The pre-frontal cortex (PFC) is one of the most complex cortical regions in the human brain. As the name suggests, it is located at the front of the brain, behind the eyes and forehead. The PFC is involved in a range of higher executive functions - working memory, information processing, behavioural organization, attention, judgement, personality, and the ability to cope with novel experiences (Roberts et al., 1998; Marieb & Hoehn, 2010).

TRIPLE NETWORK MODEL

More recent neuroscience research has revealed that rather than individual brain structures, it is the complex

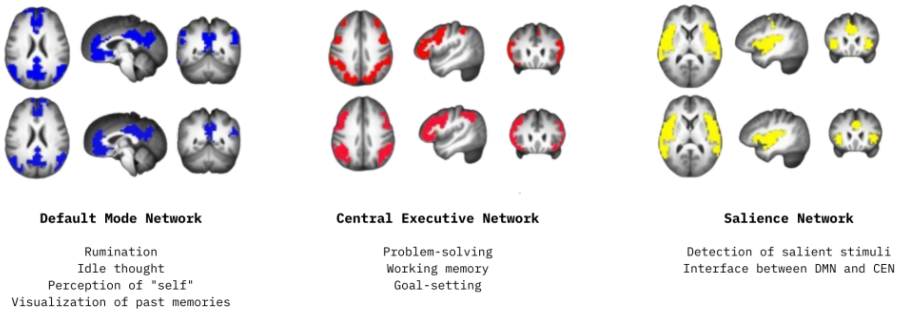

Figure 1. The triple network model.
Note. From What's the default mode network? By Cooke, J., 2021 (https://tripsitter.com/default-mode-network/)

activity within multiple networks, referred to as intrinsic connectivity networks (ICNs), that are a factor in a range of psychological pathologies (Abdallah et al., 2019; Liu et al., 2017). Referred to as the 'triple network model', the three large scale networks that make up this triad are the salience network (SN), default mode network (DMN), and the central executive network (CEN) (Liu et al., 2017), as shown in figure 1. Let's take a look at each one.

SALIENCE NETWORK (SN)

The SN is made up of several brain regions, anchored by the insula (INS) and the dorsal anterior cingulate cortex (dACC) (Abdallah et al., 2019; Chamberlin, 2019; Kamiya & Abe, 2020; Nicholson et al., 2020).

It has extensive connections with a number of important subcortical regions. Key ones are the amygdala (fear conditioning and behavioural relevance), hypothalamus (regulation of the interior milieu), and thalamus (relaying sensory and motor signals emotion, memory and arousal). Additionally, the ventral striatum (reward, cognition, reinforcement, and motivational salience), substantia nigra (production of dopamine), ventral tegmental area (reward, motivation, cognition, and aversion), and periaqueductal gray (involved in fixed action emotion motor circuits) (Chamberlin, 2019; Kamiya & Abe, 2020; Seeley, 2019).

The SN is involved in interoceptive (internal body state) processing, monitoring the surrounding environment and detecting salient (relevant) stimuli (Nicholson et al., 2020). It is also involved in homoeostatic regulation, autonomic function and reward processing (Kamiya & Abe, 2020), coactivating in response to a diverse range of tasks and conditions (Seeley, 2019).

The SN performs an important role mediating between the central executive network (task-relevant behaviour) and the default mode network (task-irrelevant behaviour) (Abdallah et al., 2019), effectively

acting as a switch between these networks (Chamberlin, 2019; Kamiya & Abe, 2020).

DEFAULT MODE NETWORK (DMN)

The DMN is a network made up of several high-level cognitive areas which include: the ventromedial prefrontal cortex (vmPFC) (emotional processing, decision-making, memory), posterior cingulate cortex (PCC) (regulates other DMN regions in task-negative states), and hippocampus (learning and memory). The precuneus, lateral temporal lobe and posterior inferior parietal lobe are also involved (Chamberlin, 2019; Kamiya & Abe, 2020; Nicholson et al., 2020; Raichle et al., 2001; Wang et al., 2019).

Functions of the DMN include episodic memory, interoception, self-referential thoughts and imagining the future (Abdallah et al., 2019; Chamberlin, 2019; Kamiya & Abe, 2020; Nicholson et al., 2020). As such, it is most active when people are focused on their internal mental-state processes, such as during mind wandering and daydreaming states, which are activities that mostly take place at rest (Chamberlin, 2019; Kamiya & Abe, 2020).

Conversely, it is deactivated during externally oriented, attention-demanding and goal-oriented tasks (Abdallah et al., 2019; Kamiya & Abe, 2020). Because of this it is often referred to as the "task-negative" network (Raichle et al., 2001).

CENTRAL EXECUTIVE NETWORK (CEN)

The CEN is a fronto-parietal and cerebellar system (Nicholson et al., 2020; Raffone et al., 2019) with major nodes anchored in the dorsolateral prefrontal cortex (dlPFC) and the lateral posterior parietal cortex (Abdallah et al., 2019; Borders, 2020; Nicholson et al., 2020). The precuneus and part of the premotor cortex are also part of the CEN (Kamiya & Abe, 2020). These regions are known to support working memory, executive function, and cognitive control processes. (Seeley, 2019).

The CEN is involved in higher order executive functions, involved in the cognitive control of thought, and maintaining and manipulating information in working memory (Nicholson et al., 2020). It is also responsible for rule-based problem solving, decision making in the context of goal-directed behaviour (Kamiya & Abe, 2020; Raffone et al., 2019) and top-down regulation of emotions. (Abdallah et al., 2019; Borders, 2020; Kamiya & Abe, 2020; Nicholson et al., 2020).

This suggests why the CEN is referred to as a "task positive network". It becomes active when a person engages ins task with the external world, for example doing a visual scan of the external environment. So, it is responsible for functions of directing eye movements, attention, and cognition (Chamberlin, 2019). It is also active during emotionally challenging activities (Borders, 2020).

In broad terms, the SN is responsible for detecting salient stimuli, emotional processing and interfacing between the DMN and CEN. The DMN is involved in autobiographical memory, rumination, idle thought, imagining the future and the perception of "self" or "ego". While the CEN is responsible for engagement with the external world, problem-solving, projecting the future and working memory. (Cooke, 2021; Chamberlin, 2019). Flexible, balanced participation and interconnectivity of all three networks is required to support optimal functioning. Activation of the DMN and CEN is like a seesaw, modulated by the SN. When the CEN is activated by a task, the DMN is deactivated, and when the CEN is inactive, the DMN is activated. When any of the networks are not functioning optimally it can lead to dysfunction in the others (Chamberlin, 2019).

WHAT HAPPENS TO THESE NETWORKS DURING PTSD?

It has been suggested there may be over-engagement of the SN, under-recruitment of the CEN, combined with changes in activation of the DMN in people with PTSD (Patel, Spreng, Shin, & Girard, 2012). Increased activity and connectivity in the SN might contribute to the hypervigilance and hyperarousal symptoms, impairing modulation of the CEN and DMN (Abdallah et al., 2019; Nicholson et al., 2020). Decreased activity and connectivity in the DMN may explain symptoms of dissociation, avoidance, and intrusive thoughts (Abdallah et al., 2019; Kamiya & Abe, 2020). While decreased activity and connectivity in CEN function may result in the cognitive dysfunction and loss of top-down emotional control (Abdallah et al., 2019; Kamiya & Abe, 2020; Nicholson et al., 2020). Figure 2 provides a good overview of this.

Consequently, for people with PTSD there appears to be wide disruption across all three networks, resulting in a range of symptoms affecting mood, cognition and behaviour (Abdallah et al., 2019; Chamberlin, 2019; Nicholson et al., 2020).

WHAT MIGHT THIS MEAN FOR MASSAGE THERAPISTS?

Massage therapy can be an incredibly valuable therapeutic approach to help those with past trauma. It is likely that during your career as a massage therapist, you will encounter clients who have PTSD. While I have provided a general introduction to the triple network, I hope it provides encouragement to read more about this fascinating topic. Having some understanding of the neurobiology involved can help you increase your knowledge and become an effective trauma-informed therapist, providing appropriate and compassionate care to your clients.

Thinking back to our foundational anatomy and physiology classes and what we learnt about the various mechanoreceptors and the different

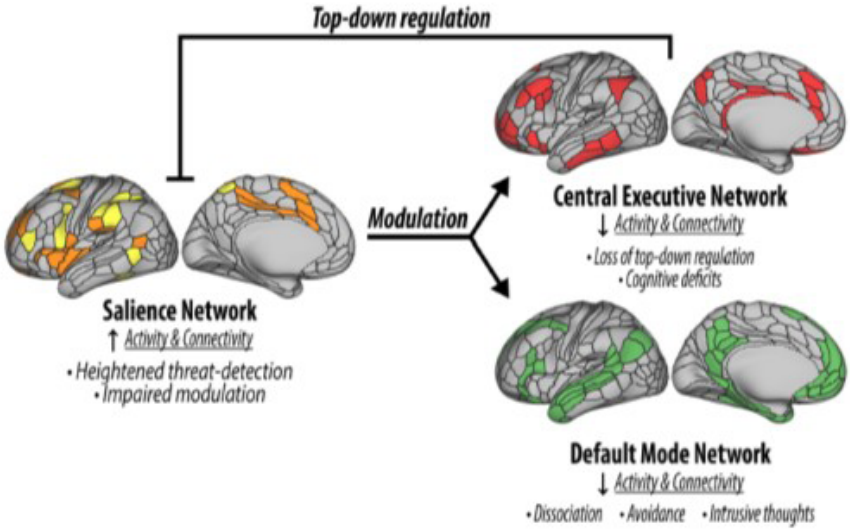

Figure 2. A network-based model of posttraumatic stress disorder (PTSD)
Note. From "The neurobiology and pharmacotherapy of posttraumatic stress disorder" By Abdallah at al., 2019, Annual review of pharmacology and toxicology, 59, 171-189.

types of input they respond to, as well as the effect of the various techniques we apply in treatment, it is worth considering how the approaches and techniques we use with clients with PTSD might affect the triple network. Given the role of the SN in interoceptive (internal body state) processing (Nicholson et al., 2020), getting clients to engage in tasks such as focusing on their breath, progressive relaxation or using several of their senses may help to decrease SN activity if they are experiencing hypervigilance or hyperarousal symptoms Abdallah et al., 2019). It may be more appropriate to focus on techniques that are calming and grounding, rather than stimulating.

As the DMN is most active during mind wandering or meditative states (Chamberlin, 2019; Kamiya & Abe, 2020), approaches that promote relaxation might support DMN activation, which may be beneficial if a client is experiencing dissociation. It is important to be aware that a recent study (Strauss et al., 2019a) showed that slow inter-personal touch (skin to skin stroking) that stimulates c-tactile afferents deactivated the DMN, however this was not done on participants with PTSD. However, another study (Strauss et al., 2019b) found that people with interpersonal traumatisation may have an aversion to such touch. The key is to do a thorough intake, ask them what their preferences are, pay attention to them during treatment and check in with them throughout the session.

If the client is in an emotionally stimulated state, then an approach that helps them to focus on the present moment might support activation of their CEN. Research on mindfulness-based interventions by Boyd et al. (2018) have shown some promise in restoring activity and functional connectivity within and between the CEN, DMN and SN in individuals with PTSD. This may suggest that bodywork that incorporates mindfulness approaches could be equally beneficial for massage therapy clients with PTSD.

I encourage you to read the other articles in this issue which provide some excellent practice insights into working with clients with PTSD.

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