ENCYCLOPEDIA on Early Childhood Development

EMOTIONS

Autonomic state: A neurophysiological platform for feelings, emotions, and social engagement

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Introduction and Subject

How does physiology influence mental processes and behaviour? I have asked this question as I studied children from birth including those with developmental challenges such as prematurity,[1] Fragile-X-Syndrome,[2] Autism Spectrum Disorders,[3] Selective Mutism,[4] Ehlers-Danlos Syndrome,[5] and Prader Willi Syndrome[6] with a common focus on identifying mechanisms that influence the regulation of behaviour and emotions. Based on my research, I developed the Polyvagal Theory,[7,8,9] which explores how neural circuits involved in the regulation of our bodily organs influence emotional responses and behaviours toward others and our environment.

There is now an abundance of research documenting that the regulation of behavioural and emotional state is mediated by the autonomic nervous system through neural pathways originating in the brainstem that communicate with organs in our body forming a bi-directional brain-body neural highway. When this system is functioning optimally, we can self-regulate and welcome others to co-regulate through social behaviour.

Problems

The parallel investigations of neurophysiology, emotion, and social behaviour during child development lead to questions of how these functional domains are inter-related. Basically, what physiological mechanisms enable or disrupt emotional regulation and sociality? How does knowledge of neuroanatomy, evolutionary biology, and autonomic state regulation inform us to better understand emotional regulation and sociality in the developing child?

Research Context

Polyvagal Theory emphasizes the evolutionary transition from ancient now extinct asocial reptiles to social mammals. Since we are mammals, we share with other mammals a virtually identical brainstem with neural structures that monitor and regulate our autonomic nervous system. The brainstem contains neural structures that regulate foundational survival mechanisms that maintain life support functions without requiring the more evolved higher brain structures required for conscious awareness and intentionality. The anatomy of the mammalian brainstem is very similar to a reptilian brainstem, which was repurposed and modified through evolution to support, in addition to defense, processes such as joyful play and intimacy.

Although mammalian, and especially humans, brains are well developed with a large cortex, their brain architecture differs from vertebrates that evolved prior to mammals. In mammals there is a great species variation in size of the cortex, as the intentional behaviours, learning, problem solving, and selective sociality increases, so does the size of the cortex. Reptiles have a very small cortex and the vertebrates that preceded reptiles such as amphibians and fish do not have a cortex.

We can conceptualize evolution as a very slow developmental process occurring over hundreds of millions of years during which there is a diversification of species or groups of organisms. During this process, although there have been major changes in the architecture of the brain, some parts of the brain appear relatively consistent across vertebrates, such as the brainstem. However, even with modifications, the foundational survival processes regulated by brainstem mechanisms continue, even in modern humans, to function outside our awareness. These survival mechanisms reflexively shift physiological state to support or disrupt homeostatic processes that support health, growth, and restoration. In response to threat, homeostasis is disrupted to support biobehavioural strategies of defense such as the metabolically costly fight/flight behaviours or metabolically conservative, but potentially lethal, death feigning reactions that are mediated by an ancient defense system shared with very ancient vertebrates and seen in humans as fainting during threat. This ancient system was adaptive for ancient vertebrates, who did not have a large cortex that would rapidly be damaged when oxygen blood saturation level drops. Small mammalian rodents have modified this ancient defense system to death feign by immobilizing for short periods to appear to be dead to an active predator. Similar responses have been reported by adults who survived severe abuse as children.

Functionally, when our autonomic nervous system is efficiently supporting homeostasis, signals from our organs travel through sensory nerves to our brainstem and then from the brainstem to higher brain structures that support a conscious awareness that we interpret as feelings of safety.[10] When homeostasis is disrupted the signals from our bodily organs are now interpreted as feelings of threat. Feelings of threat trigger an array of emotions involving the limbic system defined by structures above the ancient brainstem and outside the cortical areas involved in consciousness. The process through which bodily states are consciously detected is called interoception.

Key Research Questions

Can we document that specific cues of safety reflexively calm the autonomic nervous system to optimize emotional regulation, sociality, learning, and health related homeostatic processes? Are autonomic states reliable indicators of feeling safe or threatened?

Recent Research Results

Polyvagal Theory proposes that autonomic state functions as an intervening variable that contributes to whether we experience positive emotions and socially engage, we defensively react with fight or flight behaviours, or we immobilize and dissociate mimicking the death feigning response of a mouse in the jaws of a cat. These examples illustrate the three functional autonomic circuits in mammals[9] described below:

1. The ventral vagal circuit regulating the calming branch of the vagus, a cranial nerve with a branch connecting the brainstem and the heart. This pathway has the capacity to slow heart rate and is linked to neural regulation of the striated muscles of the face and head to

form a social engagement system enabling autonomic state to be broadcast through face and voice. In addition, this circuit can functionally manage the more primitive circuits keeping them out states of defense to support prosocial activities of play and intimacy.

2. A spinal sympathetic system supporting mobilization, which is shared with several vertebrate species that evolved prior to mammals. In mammals, if this metabolically costly system is overwhelmed it will shut down and disinhibit the ancient dorsal vagal system.
3. An ancient dorsal vagal system is shared with virtually all vertebrates. When recruited in defense conserves metabolic resources and functions to reduce oxygenated blood to reach the brain. In mammals, although adaptive for short periods of time, it is potentially lethal.

These circuits, by paralleling evolution, are hierarchically organized in which newer circuits inhibit older ones. Under threat, survival needs functionally result in a systematic disruption of this hierarchical organization in which the evolutionary older circuits are now sequentially disinhibited to optimize survival. This process was labeled 'dissolution' by John Hughlings Jackson,[11] a neurologist, who used the construct to describe the 'de-evolution' or evolution in reverse that he observed following brain damage due to disease or injury.

This hierarchy is bi-directional and through neuroception, cues of safety can dampen, and cues of danger can amplify threat reactions. The term, neuroception, is used to emphasize that the nervous system is doing the detection outside of brain areas involved in conscious intentional behaviour. Although higher brain structures may be involved in neuroception, the process is not related to conscious awareness, which would require decision making time to determine the source of the cues being detected. This decision is hardwired into a neuroception circuit to ensure that an adjustment is rapidly made to optimize survival. For example, if you hear a loud noise, you stop and then attempt to determine the origin and importance of the sound.

While virtually all evolutionarily antecedent all living organisms have a neuroception for threat, only mammals have a neuroception for safety that detects cues of safety and reflexively down regulates threat reactions. Watching a mother calm her crying baby by using a melodic (prosodic) voice, is a powerful example. The baby's cry reflects a physiological state of threat that has resulted in a disruption of homeostasis. When the mother talks or sings to her baby, the baby calms. A calmness that is observable in behaviour, muscle tone, and even autonomically in heart rate.[12] Similar calming influences of prosodic voice are observed when we calm mammalian pets such as dogs, cats, and horses.

Research gaps

Polyvagal Theory provides a perspective to investigate how of autonomic state is involved in feelings, emotions, and sociality. It provides insights into measurements of autonomic metrics that would index features of sociality and feelings of safety. It would also lead to hypotheses relating autonomic regulation features as being important potential mediators of emotional dysregulation, social difficulties, and compromised mental processes. To test these hypotheses accurate and objective measures of homeostatic function, distress, and feelings of safety are required. Moreover, given the bidirectionality of the hierarchy of autonomic states, therapeutic strategies, and new methodologies of intervention in which autonomic state would be the portal of intervention could be tested to improve both mental and physical health.

Conclusions and Implications

The human behavioural repertoire is greatly influenced by autonomic state. The neural regulation of autonomic state follows a developmental trajectory that can be disrupted by illness and early experiences including prematurity and difficult deliveries. In addition, adverse experiences during early development may functionally retuned the autonomic nervous system to be in a chronic state of threat. Polyvagal Theory provides an optimistic perspective that assumes that many of the defensive features that emerge spontaneously from an autonomic nervous system tuned to be chronically defensive are manageable through therapeutic interventions leveraging a neuroception of safety through the powerful calming influences of cues of safety.

Through evolution the brainstem area regulating the calming ventral vagus is also involved in the neural regulation of the striated muscles of the face and head. This enabled vocalization and facial expression to functionally broadcast autonomic state to conspecifics informing them that they were or were not safe to approach. This link between autonomic state and the structures that project emotion identifies neuroanatomical and neurophysiological mechanisms that support co-regulation and sociality. An understanding of this link is being embraced the therapists and educators, who are working with children chronically locked in an autonomic state of threat. This knowledge will lead to an appreciation that many disruptive behaviours are emergent properties of the autonomic nervous system being in a state of defense and not intentional nor available to be modified through punishments or rewards.

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