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Autonomic nervous system regulation and attachment patterns in children with vasovagal syncope: a theoretical framework in light of the polyvagal theory

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Abstract

Vasovagal Syncope (VVS) is an early onset syncope involving a transient loss of consciousness and postural tone. This article illustrates the implications of Polyvagal Theory (PVT) for understanding VVS as a consequence of autonomic regulation impairments stemming from attachment failures during childhood. Repetitive failures in early attachment relationships may hinder the development of the ability to adequately appraise internal and external stimuli and regulate one's emotional states. In accordance with PVT, these impairments may underlie the predominant activation of phylogenetically older emotion regulation systems, including the dorsal-vagal and sympathetic systems, over the ventral-vagal system, increasing the individual's propensity to exhibit immobilization and fight/flight reactions. In fact, inhibition of the ventral-vagal system prevents the regulation of emotional states through interactions with others and the experience of safety in social relationships. Our theoretical framework posits that VVS, including pediatric syncope, might result from altered appraisal and autonomic regulation processes. Clinical interventions aimed at fostering emotion regulation abilities and feelings of safety in social relationships might be critical for improving the well-being of patients suffering from VVS.

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1. Introduction

Syncope is defined as a transient loss of consciousness (T-LOC) and postural tone, characterized by rapid onset, short duration and spontaneous recovery, due to a transient cerebral hypoperfusion (Brignole et al., 2018). Transient cerebral hypoperfusion distinguishes probable syncope from other disorders, such as epileptic seizures and concussion (Brignole et al., 2018).

Although the onset of syncope may occur at every age, syncope is particularly common during puberty (~10 – 15 years; Kanjwal & Calkins, 2015; Wieling et al., 2004). According to epidemiological studies, the most frequent type of pediatric syncope is represented by reflex syncope also referred as vasovagal syncope (VVS) or neurocardiogenic syncope (NCS) (Da Silva, 2014), responsible for up to 80% of pediatric syncope cases (Massin et al., 2004). VVS is a neurally mediated syncope, defined as a syndrome in which triggering of a neural reflex results in a – often self-limited – episode of systemic hypotension characterized by both bradycardia (asystole or relative bradycardia) and peripheral vasodilation (Chen-Scarabelli & Scarabelli, 2004). This may be induced by mild pain, fear, or merely standing (Van Dijk & Sheldon, 2008).

Specifically, the sequela of events determining the VVS involves the Bezold-Jarisch reflex (Iwase et al., 2014; Pinna et al., 2015; Salo et al., 2007). Cerebral hypoperfusion triggers this reflex, which generates vagal activation and sympathetic withdrawal (Gunnar Wallin & Sundlöf, 1982). These autonomic alterations determine the reduction of heart rate (bradycardia) and vasodilation (hypotension), leading to syncope (Salo et al., 2007).

Besides VVS, other less frequent types of pediatric syncope are represented by: orthostatic hypotension or syndromes of orthostatic intolerance or postural orthostatic tachycardia syndromes (POTS), which is characterized by autonomic alterations and altered heart functioning (e.g., tachycardia) while standing; cardiac syncope, which is associated and dependent by arrhythmias or structural heart disease (e.g., myocardial infarction); psychogenic non-syncopal collapse or psychogenic pseudo-syncope (PPS), which is defined by the absence of cerebral hypoperfusion (Brignole et al., 2018).

Although previous research suggests that psychological and psychopathological factors may contribute to the onset of pediatric syncope (Cuzzocrea et al., 2024), the understanding of the interactions between physiological and psychological mechanisms underlying pediatric

symptoms, particularly VVS, remains limited. In fact, previous literature has predominantly focused on the pathophysiological underpinnings of VVS (e.g., Benditt et al., 2020; Longo et al., 2023). Addressing this gap, the present article aims to introduce a novel conceptual framework grounded in Polyvagal Theory (PVT; Porges, 2011). This framework integrates recent findings from psychosomatic, developmental, and neurophysiological research, offering a new perspective on the psychological and physiological mechanisms involved in VVS in children. The article first outlines the psychological and autonomic correlates of VVS. It then provides a literature overview on the role of developmental trauma and insecure attachment in the development of potentially dysfunctional emotion regulation abilities. Finally, PVT is proposed as a theoretical framework through which to understand the interaction between early attachment experiences, emotional regulation, and autonomic functioning. The clinical implications of this model are also discussed, with particular attention to psychotherapeutic interventions targeting autonomic regulation and attachment attitudes.

2. Psychological correlates of vasovagal syncope

Literature suggests that children and adolescents with VVS presented more frequent comorbid depressive, anxiety, and conversion disorder compared to healthy controls (Hyphantis et al., 2012; Kara & Doğan, 2021). Furthermore, severity of depressive and anxiety symptoms positively correlates with number of syncopal episodes (Hyphantis et al., 2012; Lee et al., 2013). Compared to children with the "true" syncope, those with PPS tend to report a greater number of psychiatric diagnoses (such as depression, anxiety, and post-traumatic stress disorder) and lower social functioning (Heyer et al., 2017).

Notably, due to the low prevalence of pediatric syncope in the population, most studies employed either a cross sectional or retrospective study design, preventing from investigating causal relationship. In fact, pediatric syncope has been also associated with higher parental burden (Blount et al., 2004; Grimaldi Capitello et al., 2016; Hyphantis et al., 2012), poor quality of life (Anderson et al., 2012; Grimaldi Capitello et al., 2016), and social withdrawal (Byars et al., 2000).

3. Autonomic correlates of vasovagal syncope

The Autonomic Nervous System (ANS) regulates systemic blood pressure aimed at maintaining constant cerebral perfusion. Cerebral perfusion tends be altered by physiological (e.g., postural variations) or emotional changes (e.g., pain, fear; Brignole et al., 2018; Hainsworth & Claydon, 2013).

Previous research has examined the activity of two branches of the ANS, specifically the sympathetic and parasympathetic systems, to investigate the autonomic correlates of VVS. The

sympathetic system is associated with, though not restricted to, initiating fight-or-flight responses to potential threats, while the parasympathetic system is involved in, but not limited to, conserving energy, promoting digestion, and facilitating the elimination of waste (Wehrwein et al., 2016). VVS episodes are typically characterized by an initial increase in sympathetic activity, followed by an increase in parasympathetic activity (Sehra et al., 1999; Stewart et al., 1996). Notably, this autonomic pattern is more evident in preadolescents with VVS than in those with just presyncope symptoms (Stewart et al., 1996).

A recent review found that children and adolescents with VVS showed increased sympathetic activity and reduced parasympathetic activity during 24-hour heart rate variability recording (Tao et al., 2019). Furthermore, pediatric VVS syncope has been associated with increased sympathetic activity and reduced parasympathetic activity at resting, the former detected by increased heart rate, the latter estimated from reduced HF (High-Frequency), RMSSD (Root Mean Square of Successive RR Interval Differences), pNN50 (Percentage of Successive RR Intervals that differ by more than 50 ms; Tao et al., 2019).

4. Developmental trauma, attachment insecurity, emotion dysregulation, and vasovagal syncope

Developmental trauma is defined as repeated ruptures and failures in the relationship between the child and the caregiver, which is characterized by lack of reciprocity and misunderstanding or denial of the child's emotional and physical needs (Schimmenti & Caretti, 2016, 2018; Van der Kolk & D'Andrea, 2010). Developmental trauma thus includes clearcut severe physical and sexual abuse, physical neglect, parental loss, but also more subtle experiences of emotional abuse, role reversal, as well as emotional neglect (Bifulco & Schimmenti, 2019; Schimmenti, 2018; Schimmenti & Bifulco, 2015). It is noteworthy that early attachment relationships characterized by sensitivity and responsiveness to a child's needs are critical for fostering a sense of security within relational contexts and for promoting the ability to reflect on one's own and others' mental states (Bowlby, 1988; Esposito et al., 2024; Velotti et al., 2022). By contrast, children who are exposed to maltreatment tend to develop maladaptive interpersonal schemata (i.e., insecure internal working models), characterized by negative beliefs on the self and the others, and dysfunctional strategies to regulate negative emotions (Bowlby, 1988; Bretherton, 1999), increasing the risk of psychopathology (Midolo et al., 2020; Stang et al., 2024). According to the attachment theory, these strategies may imply either a deactivation or a hyperactivation of the attachment system (Santoro et al., 2021). The deactivation of the attachment system is related to a tendency to minimize emotional needs and search for caregiver's care. By contrast, the hyperactivation of the attachment system is related to an amplification of emotional needs and an overdependence on the caregiver, to regulate internal states (Bowlby, 1973; Schimmenti

& Caretti, 2018). Furthermore, exposure to traumatic events may foster alexithymic features (Krystal & Krystal, 1988). Alexithymia is a personality trait characterized by difficulties in identifying and describing feelings, along with a tendency to focus on the concrete aspects of reality (Taylor et al., 1991). Although alexithymia is found to be a normally distributed trait (Parker et al., 2008), developmental trauma may impair individuals' abilities to represent and communicate feelings, contributing to a higher risk of emotion dysregulation (Schimmenti, 2017; Schimmenti & Caretti, 2018).

Recent meta-analyses have confirmed that childhood trauma and attachment insecurity are associated with alexithymia (Khan & Jaffee, 2022; Zhang et al., 2024). They were also related to elevated levels of negative emotions, greater psychological and physiological reactivity, and reduced capacity to use appropriate emotion regulation strategies (Cooke et al., 2019; Lavi et al., 2019). According to Bucci's (1998, 2001) Multiple Code Theory, childhood traumatic experiences might hinder the integration of bodily, imaginative, and symbolic correlates of emotional experience. As a consequence of dissociation between interoceptive, sub-symbolic experiences, and imaginative and/or linguistic, symbolic experiences, individuals who are emotionally aroused may experience pattern of sensory, visceral, and kinesthetic sensations, which cannot be represented and communicated, neither through images (e.g., metaphors) nor through words (e.g., expressing their feelings), thus potentially threatening and difficult to manage (Bucci, 1998). In such circumstances, individuals might use maladaptive strategies to prevent or reduce emotional arousal, such as addictive behaviors (Musetti et al., 2022; Santoro et al., 2025; Schimmenti et al., 2022). Alternatively, they might establish spurious connections between bodily arousal and external meanings, other that feelings. This might be the case, for instance, of hunger and satiety sensations in eating disorders (Di Monte et al., 2020; Di Trani et al., 2018; Mariani et al., 2022), or somatic and painful sensations in somatic symptom disorders (Solano, 2010; Taylor, 2010).

To our knowledge, only a few studies have investigated the association between pediatric syncope, childhood trauma, attachment insecurity, and emotion dysregulation. Bonadies and colleagues (2006) found that, compared to heathy controls, adults with VVS reported higher levels of childhood trauma and attachment insecurity. A a large Irish cohort study found that recurrent syncope in risk was associated with a double odds of childhood sexual or physical abuse (O'Hare et al., 2017). However, another case control study on a smaller adult sample did not find evidence of an association with early traumatic experiences (Owens et al., 2017).

Also, two studies assessing emotion dysregulation in children and adults with syncope found that, compared with healthy controls, patients with VVS and POTS showed greater trait alexithymia (Bonadies et al., 2006) and greater indices of emotional reactivity to unpleasant images during the Head Up Tilt Test (Owens et al., 2018). Furthermore, depressive symptoms and frequent syncope in youth partially mediated the effect of childhood sexual and physical abuse on recurrent syncope in adulthood (O'Hare et al., 2017). Thus, further investigations in this field are warranted.

5. The potential contribution of Polyvagal Theory to a better understanding of vasovagal syncope

The PVT (Porges, 2011) has provided a relevant framework to understand the relationship between autonomic changes, and mental and physical states, both in health and disease conditions. Integrating the findings of several disciplines, the PVT can be defined as a hypothesis driven, testable theory, based on scientific observations and principles derived from evolutionary biology, comparative neuroanatomy and neurophysiology, ethology, and developmental and clinical psychology.

PVT posits three phylogenetically, ontogenetically, and functionally ordered emotion regulation systems (Porges, 2003, 2011). These systems emerge in the same sequence both at phylogenetic level in vertebrates and at ontogenetic level in mammals. They support the individuals in coping with perceived external or internal threats, even before they become conscious, a process defined as "neuroception" (Porges, 2003). The first system is the dorsal-vagal system, shared with virtually all the vertebrates, is characterized by the use of immobilization in response to threats, and might be observed in freezing or shutting down behaviors, also described by psychoanalysis, as extreme defenses to cope with early traumatic experiences (Fraiberg et al., 1975; Winnicott, 1974). The sympathetic system is the second system and is related to aggressive or avoidant strategies (i.e., fight or flight reactions), which requires the mobilization of bodily resources and might be associated to increased heart rate, shortened breath, and increased muscle tension. The ventral-vagal system, shared with all the mammalian species, is the third, most evolved and complex system, characterized by the communication of emotional discomfort and the regulation of negative emotions though social relationship (i.e., social engagement). In fact, the social engagement system provides emotion regulation via verbal and non-verbal communication (e.g., facial expressions, head gestures, and vocal intonation) and is associated with feelings of safety, connection, and compassion.

According to PVT, emotion regulation systems are organized in a functional hierarchy, assuming that the more advanced systems tend to inhibit more ancient systems. Thus, the

activation of the ventral vagal social engagement system tends to reduce the activation of the dorsal-vagal and the sympathetic system (Porges, 2003, 2011). However, brain illnesses and disorders may lead to a reversal of the phylogenetic and ontogenetic hierarchy, preventing the superordinate systems to control the subordinate, more primitive systems, and letting them to become more active. This is defined "dissolution" or "evolution in reverse" in Jackson's (1884) theory. The PVT broaden the Jacksonian model of dissolution to the ANS functionality, proposing that when the more advanced social involvement system is no longer able to perform its calming function due to traumatic experiences, the phylogenetically and ontogenetically older defense systems (i.e., the dorsal-vagal and the sympathetic system, producing immobilization and fight/flight reactions, respectively) are activated in order to ensure safety, which is considered a biological imperative (Porges, 2021b, 2022b).

In this context, it is possible to hypothesize that VVS represents a dissolution of biobehavioral organization due to an altered neuroception, in which some environmental stimuli are misinterpreted (specifically, cues of safety and threat), and primitive and maladaptive defenses prevail over more adaptive ones.

From a developmental perspective, an altered neuroception might be viewed as a result of attachment failures and childhood maltreatment (Porges, 2003, 2011). In a secure attachment, the caregiver establishes mutual and effective co-regulation with the infant (Tronick, 2007). This emotional regulation promotes learning in the infant, i.e., the capacity to accurately appraise internal and external threats (neuroception), and the capacity of using social engagement to regulate distressing emotions (Porges, 2011; Riordan, 2022; Riordan et al., 2017). By contrast, developmental trauma is associated with a reduced capacity to manage distressing emotions and an excessive displacement of "freezing" or "fight/flight" responses related to the phenomenon of dissolution (Ogden et al., 2006; Porges, 2011; Schore, 2003; Van der Kolk & D'Andrea, 2010). Accordingly, lower vagal efficiency (VE) (Porges et al., 1999) is associated with maltreatment history and mediates the association between maltreatment history and anxiety and depression symptoms (Dale et al., 2022). Furthermore, childhood trauma is related with reduced vagal tone at resting—i.e., lower levels of Respiratory Sinus Arrhythmia (RSA) and faster heart rate—and atypical vagal response when exposed to an emotionally stressful stimulus, such as a video of maltreated children (Dale et al., 2018).

PVT is consistent with other theoretical models describing the relationship between traumatic stress and emotion regulation. For instance, Siegel (1999) proposed the concept of "window of tolerance" to define the range of tolerable emotional experiences, associated to specific level of physiologic arousal, that each individual has. People exposed to developmental trauma might experience relevant emotion dysregulation, expressed as a reduced capacity in coping with

emotional states, perceived as tolerable by most of the individuals. For instance, they might be emotionally overwhelmed and show excessive reactions (e.g., persistent anger) to neutral or mild stimuli, due to a prevalent condition of hyper-arousal. Alternatively, they might show reduced response (e.g., numbing) to emotionally significant stimuli, due a prevalent hypo-arousal of the window of tolerance (Ogden et al., 2006; Van der Kolk, 2014). Similarly, McEwen (2000) proposed that lifetime stress and inadequate social support may affect the capacity of the individual to cope with stress, determining a physiological response termed as "allostatic load". The allostatic load, although partially functional to cope with stress in the short term, might be highly dysfunctional in the long run when no longer needed, as might imply hypersensitivity or prolonged response to stressful stimuli, which may be considered expression of inadequate neuroception (Porges, 2003, 2005).

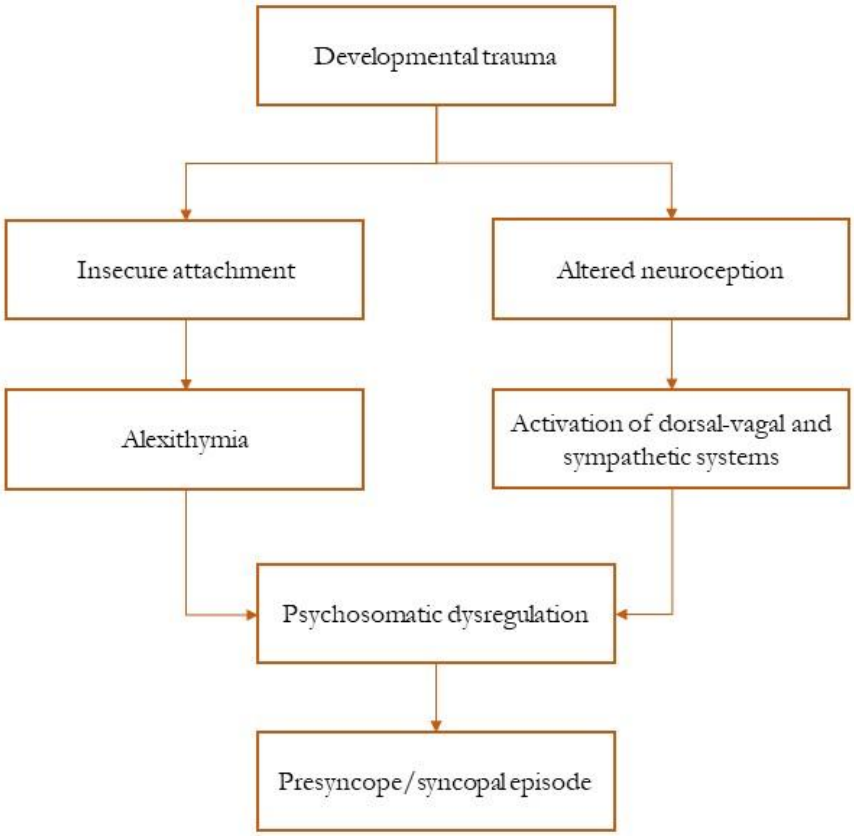
Although applications of the PVT in treatment for psychiatric disorders have only been validated experimentally in a few studies (Heilman et al., 2023; Porges et al., 2013, 2014), the PVT has received increasing support in clinical psychology (Morton et al., 2022; Poli et al., 2021; Porges, 2021a, 2021b, 2022a, 2022b; Reed et al., 1999), particularly in relation to the impact of traumatic experiences (Bailey et al., 2023; Dale et al., 2018, 2022; Kolacz et al., 2020a, 2020b; Porges, 2020; Porges et al., 2019; Sahar et al., 2001) and the treatment of post-traumatic stress (Dana, 2018; Wheeler, 2020). For instance, Dale et al. (2022) and Kolacz et al. (2020a) have recently showed that current autonomic functioning (e.g., vagal efficiency) mediated the effect of early and late adversities on depression, anxiety, and post-traumatic stress symptoms.

However, to date only a few studies have investigated the relationship between altered neuroception, autonomic functioning, and somatic symptom disorders, therefore this type of studies are particularly important. Recent studies on somatic symptom disorders, such as functional gastrointestinal disorder, cycling vomiting and fibromyalgia, suggested an altered neuroception, as shown by atypical autonomic regulation (e.g., low RSA or by low VE) in response to triggering physical and emotional stimuli (Kolacz et al., 2021, 2023; Kolacz & Porges, 2018). These findings support the idea that PVT may be a useful framework to better understand bradycardia and fainting characterizing VVS, as result of altered neuroception and impaired vagal regulation (Kolacz et al., 2021; Porges et al., 2019). However, to the best of our knowledge, the relationship between developmental trauma, vasovagal dysregulation, and VVS, has not been investigated yet.

The following visual representation (see Fig. 1) summarizes the proposed theoretical model, integrating the developmental, psychological, and autonomic pathways discussed.

Figure 1.

Theoretical model of pediatric vasovagal syncope



6. Clinical implication

Literature suggests that in addition to conventional treatment (e.g., health education and increased intake of salt and water) and, when appropriate, pharmacological treatment, psychological support should be offered to children and adolescent with VVS (Brignole et al., 2018; Liao & Du, 2020; Sheldon et al., 2015; Wang et al., 2021). In addition, we suggest that psychological treatment might help patients with VVS to experience themselves and the world from a more secure base and promote a better self-integration and more effective emotion regulation strategies, no longer expressing dissolution (Dana, 2018; Porges, 2021b; Riordan, 2022). As such, these treatments should include fostering security in the internal working models of attachment, widening the window of tolerance, and increasing ventral vagal influence. For instance, the somatic experiencing (SE) and the attachment-focused-somatic experiencing (AF-SE), that address dyadic trauma, were found to be effective treatments in reorganizing the flight/fight/freezing responses of the sympathetic nervous system and polyvagal network during access to the somatic memory of trauma (Riordan, 2022). Furthermore, recent guidelines recommend providing health education to both caregivers and their offspring to enhance their understanding of the factors that trigger syncopal episodes and to improve their ability to

manage these episodes effectively (Wang et al., 2024). These interventions might be integrated within psychoeducational programs. In fact, psychoeducational programs aimed at enhancing parental reflective functioning (i.e., the ability to represent and reflect on one's own and one's child's mental states; Luyten et al., 2017) may play a critical role in helping parents recognize their child's needs and signs of distress. This, in turn, could strengthen caregivers' capacity to appropriately regulate their child's emotional states, thereby reducing the risk of syncopal episodes.

7. Conclusion

This theoretical framework aims to contribute to the understanding of pediatric VVS in light of PVT. If the model will be verified though empirical evidence, this will promote a better assessment of psychological correlates of VVS and psychological interventions promoting attachment security, emotion regulation, and body-mind integration.

By knowing that the ventral vagal state of safety and connection is the state that supports change, therapists might wish to work with their patients toward a "mentalized embodiment" of that ventral vagal state, fostering feelings of safety and integration (Dana, 2018). Psychological interventions that are based on these premises will likely promote a better adjustment of children and adolescents suffering from VVS, relieving them from the psychological symptoms associated with fainting, fostering their mind-body integration, and ultimately promoting their normal development.

Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any potential conflict of interest.

Authors' Contribution

V.C., L.S., C.A.G., A.S. (sixth author), P.V., A.S. (thirteenth author), A.H. and S.W.P. collaborated on the conceptualization of the manuscript. V.C., L.S., C.G., G.C., C.A.G., A.S. (sixth author), P.V., I.A., F.A., A.F., M.M., A.S. (thirteenth author), A.H. and S.W.P. wrote the first draft of the manuscript. All authors sequentially revised the draft of the manuscript, providing relevant theoretical contributions. All authors have read and agreed to the final version of the manuscript.

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