Chewing on Sensory Over-responsivity and Anxiety in People with Autism and ADHD: A Review

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Abstract: There is a high occurrence of sensory over-responsivity in people with developmental disorders, especially those with autism spectrum disorders (ASD) and attention deficit hyperactivity disorder (ADHD). It was hypothesized that anxiety and sensory over-responsivity may share a common neurobiological mechanism and result from suboptimal regulation of the autonomic nervous system. In this review, the physiology of chewing, the effects of chewing on cortisol levels and autonomic activity, and the potential application of gum chewing on reducing sensory over-responsivity in people with developmental disorders were discussed. Positive effect of gum chewing on enhancing parasympathetic activity and reducing anxiety was found, and 15 minutes of chewing seems to be more effective than short periods of chewing in reducing anxiety. Further study of gum chewing on reducing sensory over-responsivity of people with developmental disorders is recommended.

***Keywords*:** autism spectrum disorder, attention deficit disorder with hyperactivity, sensory over-responsivity, anxiety, parasympathetic nervous system

1. Introduction

Sensory modulation disorder is a subtype of sensory processing disorder[1], which can make it more difficult to help these patients establish a rhythm and order in their lives that is appropriate for them. Researchers now generally agree that sensory over-responsivity occurs in 56% -79%of individuals with autism spectrum disorders and approximately 46%-69% of children with Attention Deficit Hyperactivity Disorder (ADHD)[2-4].

Children with sensory over-responsivity have higher levels of anxiety[5]. A study by Lane et al.[6] showed that ADHD children showed more than three times the rate of sensory over-responsivity than typically developing children, and anxiety scores were much higher in ADHD children.

It has been hypothesised that problems with regulation of the parasympathetic nervous system(PNS) may contribute to sensory over-responsivity and anxiety because low parasympathetic nervous system activity has been found in children with sensory over-responsivity and patients with generalised anxiety disorder (GAD)[7-10]. When parasympathetic activity is weak, sympathetic activity is more active, resulting in a faster heart rate and increased cardiac contractility, which can increase intrinsic sensory input. Sensory input is then processed through sensory processing to the final presentation of the behavioural response, and reviewing the three main aspects of sensorimotor processing[11] together with the influence of pre-autonomic activity on sensory input. The parasympathetic influence on sensory over-responsivity as a behavioural manifestation can be broadly illustrated in Figure 1. An increase in intrinsic cardiac sensory input directly makes sensory processing more cumbersome and thus indirectly or directly affects the final behavioural response.

According to the polyvagal theory, the study by Lecine et al.[12] concluded that in patients with generalised anxiety cardiac vagal tone regulation is primarily determined by the vagus nerve at the fight/flight level, and that vagal-mediated social engagement responses are considered ineffective in patients with generalised anxiety, suggesting that the parasympathetic nervous system is very inactive (Figure 2).

2. Effects of chewing on the parasympathetic nervous system

Innervation comes mainly from the mandibular branch of the trigeminal nerve, especially the auriculotemporal and occlusal branches of the mandibular nerve [13-14]. Monitoring studies of trigeminal nerve activity in rats and rabbits have found that nerve impulses generated after the onset of mastication are transmitted mainly from the upper region of the trigeminal nerve to the muscles involved in mandibular and tongue movements, forming a complete masticatory motor circuit [15-16]. One of the sources of input for increased cardiac vagal activity is the reception of nerve impulses from the

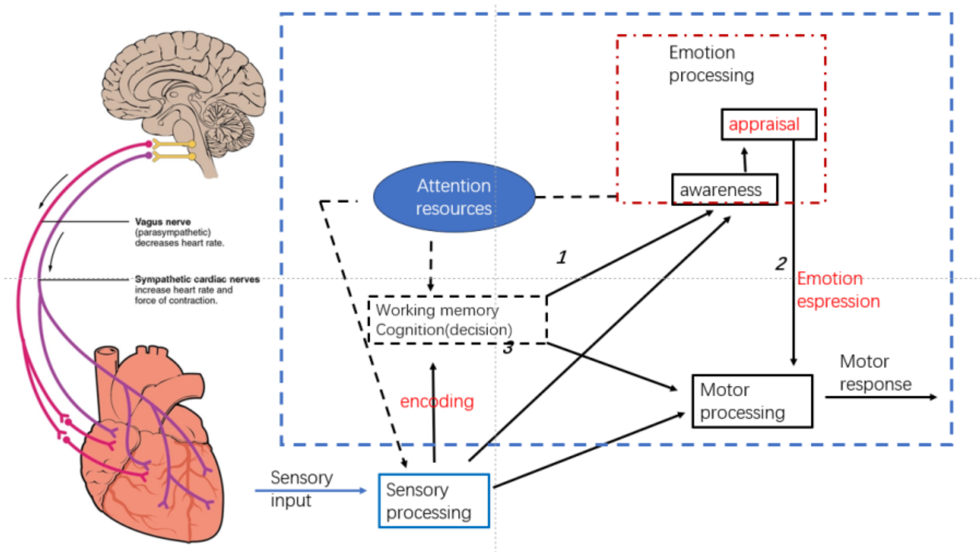

Figure 1. The parasympathetic influence on sensory over-responsivity as a behavioural manifestation

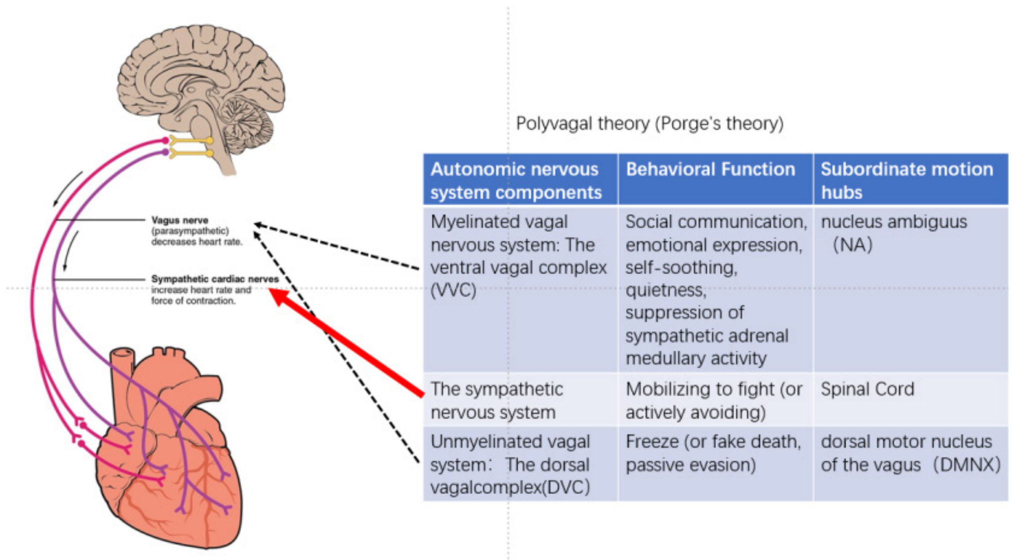

Figure 2. The parasympathetic nervous system is very inactive

trigeminal nerve [17]. Activity of the masticatory muscles activates the trigeminal cardiac reflex (TCR), which leads to increased vagal activity [17-19].

Chiou and Kuo[20] conducted a before-and-after study on 20 healthy adults aged between 18-35 years, in which high frequency (HF), low frequency (LF), and low frequency/high frequency (LF/HF) ratios were measured before and after an hour of chewing gum. It was found that LF increased significantly immediately after chewing, whereas HF increased significantly after 30 minutes of chewing gum.

Koizumi et al.[21] conducted an animal experiment to study the effect of chewing on HF and LF/HF. Rats were randomly divided into four groups: rats that were not subjected to stress (control; CT), rats that received fixed stress but did not chew (stressed group; ST), rats that were allowed to chew while receiving a fixed stress (stressed chewing group; SC), and rats that were pre-treated with propranolol before receiving a fixed stress (ProST). The results showed a significant increase in HF in the stressed rats along with a slight increase in the LF/HF ratio 2 h after chewing.

Koizumi et al. and Chiou & Kuo explained[20-21] that chewing itself may be a stimulus for sympathetic activity, but after chewing stops, it may be the main trigger for increased parasympathetic activity. This implies that chewing does directly affect autonomic activity and activates parasympathetic activity.

3. The effect of chewing on anxiety

Salivary cortisol is a clear neurophysiological marker that increases in response to physiological stress. Anxiety is a neurobehavioural manifestation of stress, and therefore changes in salivary cortisol levels can, to some extent, reflect altered anxiety states.

Tahara et al[22] conducted a study on 17 healthy men by examining their salivary cortisol levels before and after chewing paraffin wax for 10 minutes. A 15.4% reduction in salivary cortisol was found after 10 minutes of paraffin chewing. Tasaka et al.[23] also conducted a randomised controlled trial of 28 healthy men to measure cortisol levels before and after 10 minutes of chewing unflavoured chewing gum. The results of the experiment showed that the changes in salivary cortisol levels were significantly lower after 10 minutes of chewing, and the difference between the control group and the chewing group was statistically significant. Therefore, this test could suggest that the effectiveness of chewing gum in improving sensory over-responsivity may be due to the chewing action itself rather than the ingredients in the gum. However, the study did not control for the frequency of chewing and did not mention the number of participants in the control group.

Regarding the lasting effects of chewing activity, Konecˇ and Urlacher[24] recruited 29 local betel nut users in a small village. Salivary cortisol levels were measured at seven time points before and after chewing. The results showed that salivary cortisol levels were significantly lower than pre-chewing levels only at 15, 30 and 45 minutes after chewing. The average level of cortisol measured after betel nut chewing fell to about 60 per cent of the pre-chewing data. The researchers ruled out the influence of betel nut ingredients on the results and concluded that the effect of chewing on lowering cortisol levels may only last for about an hour. These findings imply that people with sensory over-responsivity may benefit from chewing activities, but the effects may not last.

Different chewing durations also have different effects on cortisol levels, and Tasaka et al[25] conducted a study in 14 healthy men examining four different chewing durations. The results showed that there was a decrease in cortisol levels after chewing, and that chewing for 15 minutes resulted in a more significant decrease in cortisol levels than chewing for 5 minutes. This implies that longer chewing times may be more helpful in alleviating sensory over-responsivity. However, the maximum chewing time in this study was 15 minutes, so it is not clear whether longer chewing times would produce better results.

4. Conclusion

Research on chewing to improve sensory over-responsivity is still in its infancy, and although experimental studies of chewing on sensory over-responsivity are limited, a large body of available evidence suggests that chewing enhances PNS activity and relieves stress and anxiety. Sensory over-responsivity is common in individuals with ASD, some individuals with ADHD, and other developmental disorders. One possible factor is poor PNS function. Chewing movements are effective in activating PNS activity via the vagus nerve. The link between sensory over-responsivity and anxiety may shed light on the potential application of chewing in reducing sensory over-responsivity in patients with developmental disorders.

However, there is no reference standard for the magnitude of effect that different regimens of gum chewing (e.g., frequency and duration) would have on its effectiveness, and current trials suggest that gum chewing for 15 minutes has a greater effect on lowering cortisol. If chewing is chosen as an intervention method, further research is recommended to investigate how gum chewing reduces sensory over-responsivity in individuals with developmental disabilities. Cooperative children with autism and ADHD could be recruited for gum-chewing trials using devices that measure autonomic changes. For example, the HRV device, paired with completion of the SensOR Inventory (Reflective Sensory Processing) and Revised Childhood Manifest Anxiety Scale (RCMAS) (Reflective Feelings of Anxiety) scales to fill the gaps in current trials.

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