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Befriending Your Vagus Nerve: A Storybook for Children

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Abstract

The vagus nerve, which is the longest of the cranial nerves, extends from the brain to the majority of organs in the body and has, therefore, been dubbed the Wanderer. It carries both sensory (afferent) information about the organs to the brain and motor information (efferent) from the brain to the organs. Stimulating the vagus nerve has been the interest of researchers since the late 1800s when delivering electricity to the nerve was used to treat acute epileptic seizures. Today, vagus nerve stimulation has been approved as treatment for morbid obesity and treatment-resistant depression as well. More natural techniques to stimulate the vagus nerve also exist. Current research shows that meditation and movement-based contemplative practices; exercising; singing, humming, and chanting; cold exposure; massage; laughing; and maintaining good gut health can stimulate the vagus nerve. All of these activities produce an increase in heart rate variability which is a measure of how well the vagus nerve is functioning. Interestingly, these natural methods of stimulating the vagus nerve have been an element of mindfulness practice for millenia. Since the natural methods are easily taught and sustained; non-invasive; low cost; and low risk, they are very suitable for improving the well-being of young children. One age-appropriate way to educate children on how to easily stimulate the vagus nerve is a storybook.

Keywords: vagus nerve, mindfulness, natural ways of stimulation, heart rate variability, children, storybook

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Creative Project

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The term *nervus vagus* was first used to name the tenth cranial nerve by Caspar Bartholin the Elder in 1611 in *Institutiones Anatomicae* (Porzionato et al., 2013). Since then, the understanding of the vagus nerve's link to the brain has increased dramatically. When the vagus nerve is working well individuals have, for example, fewer respiratory, digestive, and cardiovascular problems. Furthermore, a high vagal tone, which is an indicator of a well-functioning vagus nerve, is related to, for instance, increased prosociality and reduced anxiety, depression, and reactive behavior. In sum, an adaptive vagus nerve is central in coordinating the body's ability to react and recover from stressors which are directly related to physical and mental well-being (e.g. Dedoncker et al., 2021).

The vagus nerve is a part of the autonomic nervous system that regulates our involuntary physiologic processes. The Wanderer can be stimulated using a device that sends electric impulses. More natural methods such as meditation, yoga, singing, exercising, cold water exposure, massage, laughing, and maintaining a healthy gut flora can also improve the function of the vagus nerve. Interestingly, all of these methods can be linked to mindfulness exercises that have been practiced in Buddhism for thousands of years.

While information about the vagus nerve is being shared with adults from popular magazines (e.g. Skipper, 2020) to academic journals (e.g. Porges, 2022), there seems to be a lack of literature educating children on the topic. This is somewhat surprising for three reasons. First, in addition to the physical and mental strain caused by the pandemic, matters such as the current political divisiveness, and concern for the environment are causing children a great amount of stress. Second, the ways in which the vagus nerve can be activated are very easily taught and sustained, non-invasive, low cost, and low risk and, therefore, safe for children. Third, studies have shown the therapeutic and preventative

benefits of a healthy vagal tone in children. For example, higher vagal tone was found to buffer children exposed to frequent marital conflict against increased externalizing, internalizing, and health problems (El-Sheikh et al., 2001) and moderate vagal tone predicts increased prosociality in children (Miller et al., 2017). In contrast, low vagal tone is linked to poor emotional and attentional regulation in children (McLaughlin et al., 2015).

This paper takes a mind-body approach by studying the physical function of the vagus nerve and linking the ways in which it can be stimulated to age-old mindfulness practices. More specifically, the paper will 1) introduce the anatomy and functions of the vagus nerve, 2) explain why it is beneficial to have an active vagus nerve and how the activity level can be measured, 3) examine seven natural ways to stimulate the vagus nerve, and 4) present the rationale for creating a storybook that educates young children about the vagus nerve. The final part of the paper is a creative project that in a concrete way addresses the gap in literature by presenting a storybook for children about the vagus nerve.

Anatomy and Functions of the Vagus Nerve

The vagus nerve, or the tenth cranial nerve, is the longest of the cranial nerves. Unlike the other cranial nerves, the vagus nerve leaves the head extending to the majority of organs in the body connecting the brain-stem to, for instance, the heart, lungs, kidneys, liver, spleen, gallbladder, stomach, and small intestines. In addition, the vagus nerve connects to the muscles in the throat and neck. In Latin, vagus means wandering and the vagus nerve has been dubbed as the wanderer due to its extensive distribution through the body.

The vagus nerve is a mixed nerve that carries not only sensory (afferent) information about the functions of the organs to the brain but also motor (efferent) information from the brain to the organs. The ratio of afferent and efferent fibers is 80% and 20%, respectively, making the most important function of the vagus nerve thus afferent. Furthermore, the wanderer is a crucial part of the parasympathetic nervous system that calms the organs to rest

and digest mode after the sympathetic nervous system has alerted them into fight or flight mode. The strength of connection between the brain and the body is called the vagal tone and it represents the activity of the vagus nerve. Low vagal tone indicates low tolerance to stress and difficulty in resting and recovering. In contrast, high vagal tone means high emotional regulation and ability to rapidly decelerate from stress to calm.

When a person becomes stressed, their heart rate (HR) increases as the sympathetic nervous system prepares to fight or flee. The parasympathetic nervous system decreases the HR when the perceived danger is over. Measuring heart rate variability (variation in time between each heartbeat) can, therefore, indicate how well the vagus nerve is functioning. When heart rate variability (HRV) is high, the person's nervous system is in balance and it is able to respond well to both the parasympathetic and sympathetic input. On the other hand, low HRV suggests that the nervous system is in a state of imbalance often leaning towards the sympathetic side. In order to promote well-being, we should not be reactive and get stuck in survival mode but instead be flexible in our responses to the challenges that we encounter.

According to the Polyvagal Theory by Porges (2022), stimulating the vagus nerve presents a way in which we can restore and maintain calm. Our feeling of safety is dependent primarily on autonomic states that are complemented by our cognitive assessment of risk factors in our environment, such as a potentially harmful relationship. Our estimation of being safe is a subjective evaluation. It is, for example, possible that even when a threat is removed, a person still does not feel safe. The Polyvagal Theory (Porges, 2022) states that we should identify that our body is responding to a threat and then ask ourselves how we can trigger our body into feeling safe again. For example, a lullaby sung to a baby or calming music played to a patient in therapy can help override the feeling of a threat. In fact, Ryland et al. (2022) recommend that therapists use polyvagal theory to normalize patients' resistant behaviors as they "emerge from an adaptive, preconscious system that seeks to protect us" (p.

270). Normalizing the protective behaviors creates a feeling of safety which is fundamentally important for healing to begin.

Stimulating the Vagus Nerve

Already in the late 1800s, vagus nerve stimulation (VNS) was administered by delivering electricity to the vagus nerve (Badran, 2022). The first such stimulation for medical purposes was performed by a neurologist with the aim of treating acute epileptic seizures. Since then, VNS has been tested in the treatment of anxiety, Alzheimer's disease, and migranes as well (Groves & Brown, 2005). Burger et al. (2019) discovered that transcutaneous auricular vagus nerve stimulation (taVNS) reduced spontaneous thought intrusions in high worriers. In taVNS, a person can clip electrodes to their ear and a portable external pulse generator will deliver electrical stimulation to it (Badran, 2022). Today, the U.S. Food and Drug Administration (FDA) has approved VNS for the treatment of epilepsy, morbid obesity as well as treatment-resistant depression (Badran, 2022). VNS is currently receiving a great amount of interest. For instance, a large clinical trial involving 72 clinical sites and 1,000 patients with severe depression is currently underway (Badran, 2022).

While the studies using VNS are promising and the taVNS offers a rather inexpensive, non-invasive and self-administered option for stimulating the vagus nerve, not everyone has access to the technology. There are, however, studies showing that natural techniques that can stimulate the vagus nerve and promote well-being also exist. Research indicates that the vagus nerve can be stimulated in such simple ways as yoga and meditation (e.g. Poli et al., 2021); exercising (Kai et al., 2016); singing and chanting (e.g. Tanzmeister et al., 2022); cold exposure (e.g. Jungmann et al., 2018); massage (e.g. Lu et al., 2011); laughing (e.g. Fujiwara & Okamura, 2018); and taking care of gut health (e.g. Kolacz et al. 2019).

Natural Ways of Stimulating the Vagus Nerve

This portion of the paper will show how the aforementioned natural methods of stimulating the vagus nerve have been a part of mindfulness practice for millenia already. It will also present studies on how the particular stimulation of the vagus nerve affects HRV which has been deemed a highly reliable way to measure the activity of the vagus nerve.

Meditation and movement-based contemplative practices

Meditation is central to the Buddha's teaching. The aim is to either produce calm and well-being (Samatha) or insight (Vipassana) (Shaw, 2019). Meditation is usually practiced in a seated position with little or no movement (Oman, 2019) although walking meditation is also possible. Yoga and Tai Chi are examples of movement-based contemplative practices (MBCP). They also contain interoceptive, proprioceptive, and kinesthetic awareness that is inherent to meditation (Schmalzl et al., 2014). While mostly containing intentional self-movement, MBCP can include subtle internal sensations of movement as well. In Qigong, for example, a large movement is often followed by a small movement and, as a last step, the practitioner is completely still experiencing only an internal or imagined movement. All that moves anymore is the Qi or the vital energy that fills the universe. Yoga also includes physical positions or asanas where one is entirely still. Regulated and attentively guided breathing is present in all of the practices mentioned above.

Breathing is an important way in which the vagal tone can be stimulated. For example, Laborde et al. (2019) showed that a 30-day slow-paced breathing intervention increased overnight cardiac vagal activity. Gerritsen and Band (2018) suggest that it is in fact the vagus nerve that explains the effects of contemplative practices on physical and mental health. The review articles by Kim et al. (2013) and Poli et al. (2021) also confirmed that mind-body practices promote parasympathetic activity and increase vagal tone.

Diaz-Rodriguez et al. (2021) conducted a study in order to measure the effects of a 4-week meditation program on caregivers (n = 19). Once a week, the experimental group

participated in a 4-hour session that contained theory on the benefits of meditation, yoga-like mobility, flexibility, and balance exercises (e.g. downward dog, child's pose), breathing exercises, and body awareness exercises (e.g. body scan meditation and visualization). The meditation intervention improved the HRV of the experimental group compared to the control group (n = 19) that only received an information sheet on theory and practice of meditation. Blase and van Waning (2019) also examined the effects of meditation on HRV. All subjects (n = 20) engaged in a six-week practice of Shamatha meditation that entailed elements such as breath meditation, awareness of awareness, lovingkindness meditation, and Tonglen where compassion is cultivated through visualization. As a result of the intervention, 85% of the subjects were able to better balance their autonomic nervous system. The authors concluded that the increased vagal tone was able to counterbalance the sympathetic nervous system with the help of meditation. Telles and Raghavendra (2011) found the meditation technique *dhyana* (state of mental expansiveness), rather than *dharana* (focusing attention on Om), decreased the heart rate and reduced the sympathetic activity of male Indian meditators. The researchers suggest that the increased relaxation produced the decrease in heart rate and increase in HRV.

Kromenacker et al. (2018) found that slow yogic breathing effectively activated the vagus nerve. According to Sullivan et al. (2018), the breathing techniques used in yoga have a direct effect on cardiac vagal tone. Research by Mason et al. (2013) suggests that 5-6 breaths per minute can increase vagal and parasympathetic activation. Khattab et al. (2007) had 7 men and 4 women (26-58 years) train Iyengar yoga 90-minutes per week for a duration of 5 weeks and discovered that the intervention produced a significant increase in HRV parameters associated with vagal tone. Khunti et al. (2023) reviewed 21 peer-reviewed research papers on the effect of school-based yoga on children's mental health. The overall

finding of the studies was that yoga could be a potential preventative measure for mental health issues among children and adolescents.

Tai Chi is a type of Chinese martial arts that combines balance, movement, breathing and concentration (Tai et al., 2018). Tai et al. (2018) discovered that healthy adults (n = 26) practicing Tai Chi synergy T1 once a week for 60 minutes for 10 weeks enhanced their parasympathetic modulation compared to the control group (n = 23) that did slow walking for the same duration of time. Based on measures of HRV, the autonomic activity of the experimental group showed significant decrease in the sympathetic tone and increase in the parasympathetic tone post intervention. In addition to Tai Chi, the Tai Chi synergy T1 program contained elements such as yoga, Qigong, and mantis boxing.

Chang (2015) conducted a study that focused only on the effects of Qigong. For 30 minutes 3 times a week for 12 weeks, the experimental group (n = 47) practiced eight-form moving meditation that instructed them to "relax the mind, bring the mind to the body during movement exercise, and become aware of the breathing process" (Chang, 2015, p. 1388). The control group (n = 30) simply lived life as usual. The study indicated that the experimental group had significantly enhanced HRV. The study by Lee et al. (2023) compared the HRV variability of 125 (92.5% female) cancer survivors that chose either a Qigong, mindfulness, or control group. The Qigong contained inhalation and exhalation exercises, gentle extension of the limbs, standing pole exercises, seated meditation, and leg massage taught by a martial arts instructor. The mindfulness intervention contained meditation and unspecified mindfulness practices taught by a psychological counseling professor. The qigong and mindfulness sessions took place once a week for 2 hours for a duration of 12 weeks. It is unclear how the control group was instructed. All groups also received teaching in proper nutrition. HRV was measured pretest and posttest as well as during a follow-up (3 months after the intervention). The results showed that the intervention groups significantly improved

in areas such self-emotional regulation and relieved autonomic dysfunction in the short term. The authors emphasize the importance of consistently implementing mind-body practices for improved results.

Exercise

According to the Buddha, a strong and healthy body is the foundation for spiritual life (Wright, 2020). While there are examples of enormously strenuous athletic performances such as the extreme running of the monks of the Tenday order and the demanding pilgrimage to Mount Kailash, the Buddha did not advocate ascetism. Instead, Buddhism promotes moderation in exercise and a middle way between no exercise and extreme exercise. In Cankama Sutta (A.N. 5.29), the Buddha argues the benefits of walking meditation:

> Monks, there are these five benefits of walking up & down. What five?
>
> One is fit for long journeys; one is fit for striving; one has little disease; that which is eaten, drunk, chewed, tasted, goes through proper digestion; the composure attained by walking up & down is long-lasting. These, monks, are the five benefits of walking up & down. (AN 5.29)

The regularity of physical practice is also important. Buddhist monks used to go on alm rounds which was a regular daily exercise (Shaw, 2014). Today, the Dalai Lama, for example, walks outdoors every morning and, in the case of rain, on his treadmill (His Holiness the 14th Dalai Lama of Tibet, n.d.). Respiration is fundamental in both meditation and exercise. The following paragraphs examine how breathwork during exercise can activate the vagus nerve.

Exercise initially increases sympathetic tone while decreasing cardiac vagal activity. However, after the exercise ends, vagus nerve activity increases as the body seeks to return to rest. Kai et al. (2016) examined the effect of interval training on ten healthy 21-22-year-old volunteers. They showed that training in intervals made it “possible to increase the vagus

nerve activity without increasing the sympathetic nerve activity" (Kai et al., 2016, p. 3). Guiraud et al. (2013) demonstrated that patients with chronic heart failure benefited from a single session of high intensity interval exercise (HIIE). Their heart rate reduction after HIIE was] directly correlated the improvement of vagal modulation (Guiraud et al., 2013, p. 1865).

Nagai et al. (2004) studied the impact of a long-term moderate physical training program on children aged 6-11 years. Following a 1-year mild intensity and short duration (20 min/day) training program, children who had low HRV showed significant improvement in all the frequency components of HRV. Gutin et al. (2000) conducted a study on the effects of regular exercise on 79 obese children aged 7-11 years. The results showed that exercising regularly improved the fitness and body composition of the children and had a positive effect on their parasympathetic activity (Gutin et al., 2000, p. 12). When the training ceased, the values declined. The researchers argued that adopting a lifestyle that promotes higher levels of HRV already in childhood will benefit a person in adult years.

Singing, Chanting, Humming and Listening to Music

The Buddhist canon law prohibits monks and nuns from listening or producing vocal music for entertainment. Singing can create attachment to one's voice, cause others to become attached to the voice, dissatisfaction in the celestial deities, incorrect pronouncing, and distort the meaning of the scriptures (Liu, 2018). Nevertheless, the human voice is crucial for monastic life as it can enhance religious practices. The canon law distinguishes three kinds of vocal music: singing, reciting, and chanting. Singing is defined as having secular content with melody, reciting is religious in content without melody, and chanting is about religious content with melody. The Buddha listed five benefits of chanting: not becoming physically or mentally tired, not forgetting the content, not damaging voice, and making language easy to comprehend and pleasant for celestial deities (Liu, 2018). Music is very present in Zen Buddhism, for example, as all seated meditation typically includes chanting

(Wright, 2020). The chanting exposes the meditator repeatedly to the sutras. It also connects them to the sangha of all others chanting in the same room and around the world. Furthermore, the chants are a way to express gratitude to the long line of Buddhist teachers. The ensuing paragraphs will examine how producing vocal music can stimulate the vagus nerve.

The vagus nerve runs through the esophageal hiatus of the diaphragm, which is our main respiratory muscle. Moving the diaphragm stimulates the vagus nerve and, therefore, the parasympathetic nervous system. The vagus nerve is also connected to our vocal cords. Therefore, acts such as singing can activate and stimulate the vagus nerve. Vickhoff et al. (2013) argue that singing is "a form of guided breathing" (p. 1). They studied the effects of humming, singing a hymn, and singing a slow mantra on HRV. Humming is the least coordinated of the three types of singing, as it has no temporal structure and the subjects in the study were instructed to breathe at will. The mantra, on the other hand, is the opposite as the instruction and structure allow for no individual choice and the breathing of the subjects was very regulated. The hymn is between singing and humming as the structure of every song dictates a favored way of breathing. Vickoff et al. (2013) concluded that singing can turn on the vagal pump that relaxes the singer. The findings of Tanzmeister et al. (2022) confirm the vagal stimulation resulting from singing. Their study found that both paced singing (at 0.1 Hz) and paced breathing (at 0.1 Hz) led to an increase in LF-HRV which indicates dominance of the parasympathetic nervous system. The researchers concluded that slow paced singing can offer an alternative to slow breathing such as yogic breathing.

When audibly chanting, one can feel a vibration around the ears. The study by Kalyani et al. (2011) suggested that the sensation is also diffused through the auricular branch of the vagus nerve producing limbic deactivation and rest. The intervention group was trained to chant OM (O for 5 seconds and M for 10). Their functional Magnetic Resonance Imaging

(fMRI) analysis indicated significant deactivation in areas such brain areas as the amygdala, anterior cingulate gyrus, and hippocampus insula. The amygdala, for example, initiates the fight or flight response. This suggests that the chanting produced limbic deactivation that was mediated through the branches of the vagus nerve attached to the ear.

Even merely listening to music appears to stimulate the vagus nerve. Lin et al. (2013) discovered that listening to music by Mozart reduced epileptiform discharges in children with epilepsy. The exposure to music demonstrated an increase in parasympathetic tone in the majority of the subjects. Filippa et al. (2022) discovered that listening to music can enhance vagal activity even in newborns. Their study showed that live maternal singing, rather than speaking, increased vagal activity in preterm infants in the short-term.

Cold Exposure

Ancient Tibetan Buddhist monks were known to meditate in extremely cold temperatures (Wright, 2020). Tummo meditation involves a particular kind of breathing technique that activates the sympathetic nervous system (Kozhevnikov et al., 2022). With Tummo breathing, meditators are able to increase their body temperature and, therefore, sustain the cold. Even if one is not able to master the fire breath of Tummo, exposure to cold is difficult to ignore and can force a person to pay attention to the present moment. Noting the cold but sustaining it for a longer time can be compared to learning to ignore the discomfort of sitting for extended times in sitting meditation.

When immersed in cold water, the body's HR first increases and then starts to decrease. While the magnitude of the response varies between individuals, it is an ability that can be trained (Lundell & Ojanen, 2023). Even the mere feeling of wet and cold on the face and nostrils is enough to activate the parasympathetic nervous system (Lindholm and Lundgren, 2009). The next paragraphs introduce studies showing the effect of cold stimulation, cold-water immersion, and cryotherapy on the parasympathetic and vagal tone.

Jungmann et al. (2018) exposed 61 female participants to cold stimulation on the neck, cheek, and forearm. They found that cold stimulation in the lateral neck area had a significant effect and suggested an increase in cardiac-vagal activation. Al-Haddad et al. (2010) discovered that cold water immersion (10-12°C) immediately after exercise accelerated parasympathetic reactivation and increased vagal-related indices of HRV in the 13 subjects. Ravier et al. (2022) studied the effects of cold water immersion on the HRV of 18 French elite female handball players post-exercise. They found that 1) a cold-water immersion 60 minutes after exercise increased the athletes' parasympathetic activity beyond baselines and that 2) a 6-minute cold water immersion improved cardiac vagal tone more than passive rest. Al Haddad et al. (2010) found that water immersion was a simple and effective way to immediately activate the parasympathetic nervous system post-exercise. The researchers also suggested that colder temperatures may be more effective in producing such an effect. Almeida et al. (2016) tested the effects of cold water immersion with different durations and temperature variations and recommended 15 minutes at 14°C if restoration of cardiac autonomic modulation is the goal. However, Al-Haddad et al. (2012) reported that merely 5 minutes of daily cold water immersion (15°C) can reduce post-exercise decrease in parasympathetic activity.

In the context of Finland, cold water exposure is a regular practice for many Finns as they cool down after spending time in the sauna either by immersing themselves in a lake or sea, rolling in the snow, or by taking a cold shower (Heinonen & Laukkanen, 2018). A person's heart rate in a hot sauna can increase to a level that corresponds to low- or moderate-intensity exercise (Heinonen & Laukkanen, 2018). Sauna bathing, therefore, first activates the sympathetic nervous system by exposing a person to extremely hot temperatures and then activates the parasympathetic nervous system via cold water immersion. According to Huhtaniemi and Laukkanen (2020), bathing in the sauna enhances autonomic nervous system

balance which results in an increase in vagal tone and a decrease in sympathetic tone. Sauna bathing is common among Finnish children as well: a reported 98.5% bathe in the sauna and over 90% of them do so at least once per week and nearly half 2-3 times a week (Markkola et al., 1989).

Louis et al. (2015) exposed 30 males to whole-body cryotherapy and found that resting vagal-related HRV indices increased. Mäkinen et al. (2008) studied the effects of cold habituation on the sympathetic-vagal balance. The researchers found that "cold habituation lowers sympathetic activation and causes a shift toward increased parasympathetic activity" (Mäkinen et al., 2008, p. 875). In their systematic review, Lundell and Ojanen (2023) found studies to be coherent in reporting predominant activation of the parasympathetic nervous system during diving in very cold water. These studies support the notion that exposure to cold can offer a noninvasive way to stimulate the vagus nerve.

Massage

While the Buddha did not allow massage for the purpose of pleasure, therapeutic aims were acceptable. The origins of traditional Thai massage, or Nuad Bo'Rarn, are attributed to Dr. Shivago Komarpaj a Buddhist physician who lived in India about 2,500 years ago. His teachings reached Thailand via the introduction of Buddhism as Indian monks offered people preventative care and healing in Buddhist monasteries and temples. Thai massage is deliberately slow, rhythmic, and meditative (American Organization for Bodywork Therapies of Asia, n.d.). It combines acupressure, yoga asanas, and Zen shiatsu. Inspired by Buddhist teachings, the practice contains mindfulness, lovingkindness, compassion, sympathetic joy, and equanimity. The subsequent paragraphs will survey studies on how massage can stimulate the vagus nerve.

Tactile stimulation of the head and neck area can increase vagal nerve activity non-invasively because vagal sensory neurons innervate those parts of the body. Meier et al.

(2020) randomly dispersed 60 healthy women to a vagus nerve massage, a soft shoulder massage, or a control group that simply rested. A Polar heart rate sensor was used to measure high frequency HRV (HF-HRV). The results indicated that while there was no difference between the two intervention groups, they both showed significantly higher HF-HRV than the control group.

The study by Feldman et al. (2010) showed that maternal touch reduces the stress response in infants during simulated maternal deprivation. They (Feldman et al., 2010, p. 277) call for more research on "the impact of momentary and stable forms of touch on the human infant's ultimate capacity to manage stress throughout life". In their review of the research on infant vagal tone, Field and Diego (2008) noted that stimulation of pressure receptors has been found to increase vagal activity. More recently, Diego et al. (2014) applied massage therapy to 15 preterm infants and measured their parasympathetic nervous system activity. The babies who were stroked with moderate pressure for a period of 10 minutes showed increased cardiac vagal activity and weight gain. In contrast, the infants who exercised (kinesthetic stimulation) only exhibited weight gain.

Lu et al. (2011) studied older patients in their 50s and 60s to see if foot reflexology could increase vagal modulation and decrease sympathetic modulation. They found this to be the case following of a 60-minute session where the thumb and the fingers were used to apply pressure in order to stimulate all reflex zones in the participants' feet. The authors point out that foot reflexology in addition to being non-invasive and non-pharmacological demands little time and requires no special equipment or venue. This makes it a particularly accessible way to stimulate the vagus nerve.

Laughing

The Vinaya, or Buddhist monastic code prohibits laughing (Hongladarom, 2013). After one monk, being tickled, laughed so hard that he died, tickling was banned as well.

There are, however, instances where the Buddha himself combines laughter with serious teaching. In such cases, the laughter has Right Intention and it does not, violate Right Speech by mocking, for example. The Dalai Lama has argued that wholehearted laughter and a warm heart are keys to happiness (Abrams, 2022). When we laugh, we are in a no-mind state without being attached to any expectations. Instead, we are in a child-like, open state without trying grasp anything. The following paragraphs examine the effects produced by stimulating the vagus nerve with laughter.

According to Scott et al. (2014), "[l]aughter is one of the positive emotional expressions which are expressly linked to a physiological reduction in the stressful reactions to negative emotions (e.g., fear, anger, disgust)" (p. 619). In other words, laughter can assist in de-escalating negative emotional experiences. As a person laughs, their heart rate and pulse increase much like during exercise (Citardi et al., 1996; Law et al., 2018) and the sympathetic nervous system initiates a fight or flight stress response in the body. This, in turn, activates the parasympathetic nervous system that seeks to restore calm.

Luschei et al. (2006) note that in addition to the respiratory system, the laryngeal system is active in laughing. The vagus nerve has branches in the neck and innervates the majority of the intrinsic muscles of the larynx. This suggests that the activation of the vocal cords and the larynx by laughing can stimulate the vagus nerve. Smyth et al. (2003) studied the side effect of chronic vagus nerve stimulation in 74 children (mean age 8.8) with medically refractory epilepsy. The patients had all been implanted with a vagal stimulator. Several children experienced stimulation-induced symptoms such as outbursts of laughter. This appears to further confirm that stimulating the vagus nerve and laughing are connected and that they influence each other.

The cardiovascular effects of simulated and spontaneous laughter were compared by Law et al. (2018). The researchers found that simulated laughter may have more pronounced

effects on heart rate and HRV. Laughter yoga is an example of simulated laughter. Dolgoff-Kaspar et al. (2012) conducted a laughter yoga intervention that included stimulated laughter, chanting, breathing exercises, and meditation. The participants had a total of seven laughter yoga sessions over three weeks. The researchers discovered that after the intervention the subjects showed increased HRV which signals a balance between the parasympathetic nervous system and the sympathetic nervous system. It should, however, be noted that Oliveira and Arriaga (2022) conducted a systematic review of the effects of laughter on HRV and found the results to be inconsistent. The authors called for higher quality studies to evaluate the benefits of laughter on HRV.

Yoshikawa et al. (2019) studied the effects of laughter therapy on 17 subjects of 60 years and over. During 4 weeks, they attended a 30-minute stand-up comedy session performed by a professional comedian once a week. The researchers reported a significant reduction in the HR of the subjects and estimate that it was induced by parasympathetic activation. Lackner et al. (2014) measured the heart rate of subjects as they viewed humorous films (the control group watched neutral material). They found that the heart rate, total HRV, and sympathovagal balance increased during viewing humorous films.

Fujiwara and Okamura (2018) had Japanese students listen to the sounds of people laughing for five minutes. They used a Polar heart rate monitor to measure HRV. The results indicated that listening to laughter for 5 minutes (intervention group) alleviated stress better than simply resting (control group) for the same amount of time. The researchers (Fujiwara & Okamura, 2018) discovered that simply hearing laughter increased parasympathetic nervous activity as it “improved the recovery process of the autonomic nervous system after a stress load” (p. 1). The authors drew attention to the low cost and easy access of the laughter intervention.

Gut Health

The Buddha's instructions were to practice moderation in eating. According to the Donapaka Sutta, he told engorged King Pasenadi: "When a person is constantly mindful / And knows when enough food has been taken, / All their afflictions become more slender / - They age more gradually, protecting their lives" (Olendzki, 2013). Olendzki (2013) points out that the Buddha is suggesting that eating healthily will serve both physical and spiritual goals. The connection between body and mind highlighted by Thich Nhat Hanh as well in his book *How to Eat* (2014). He points out that what and how much we eat is important as we are what we consume. Thich Nhat Hanh also wrote *Savor: Mindful Eating, Mindful Life* (2011) with nutritionist Lilian Cheung which further emphasizes the interconnectedness between our body and mind. Moreover, the study by Sun et al. (2023) discovered that meditation can positively affect the nervous system via the intestinal flora. The gut microbiota composition of 37 Tibetan Buddhist monks who had meditated for a minimum of 2 hours per day for an average of 18.94 years was significantly richer and more diverse than that of the control group of lay people (n = 19). The following paragraphs explore the role of the vagus nerve in the gut brain axis.

The vagus nerve links the viscera with the brain transmitting information in both directions. In the beginning of the 20th century, gastrectomies performed to treat peptic ulcers resulted in the removal of part of the vagus nerve as well (Fülling et al., 2019). This inhibited the vagus nerve from carrying information between the brain and the lower gastro-intestinal tract resulting in an increased number of psychiatric disorders in the patients. Multiple animal studies have also shown that the intestinal microbiota, the gut, and the central nervous system are in direct interaction via the vagus nerve (Bravo et al., 2011). Ingestion of Lactobacillus rhamnosus reduced anxiety- and depression related behavior in all mice apart from those that had been vagotomized (Bravo et al., 2011). Bercik et al. (2011) discovered that vagotomized

mice did not exhibit anxiety-like behavior associated with chronic colitis. Furthermore, the anxiety-reducing effects of Bifidobacterium longum required vagal integrity.

Recent human studies have confirmed the gut-brain connection and the vital role that the vagus nerve has in conveying information between the two entities. A low vagal tone can be observed in people with digestive disorders and inflammatory bowel diseases (Bonaz et al., 2016). Kolacz et al. (2019) found that psychiatric disorders such as anxiety and depression often coincide with functional gastrointestinal disorders which further confirms the gut-brain connection. The study on the effects of gut microbiota on depression by Irum et al. (2023) emphasized the crucial role of the vagus nerve in "establishing a clear communication pathway between bacteria, the gut, and the brain" (p. 4). The vagus nerve was identified as the main component of communication between the gut and the brain in the study conducted by Wu et al. (2022) as well. As has been mentioned earlier, the vagus nerve is bidirectional. It carries information from gut microbiota to brain and vice versa. In the former instance, microbiota can affect anxiety by influencing brain neurochemistry and in the latter, psychological stressors can alter gut microbiota composition and gut function, for example (Carabotti et al., 2015). Longo et al. (2023) suggest that the microbiota-gut-brain axis be explored further in relation to metabolic diseases such diabetes and obesity. They argue that the vagus nerve "plays an essential role in eating behavior by modulating appetite and learning nutritional preferences" (Longo et al., 2023, p. 1). Also, in obesity, vagal nerve responsiveness seems be impaired (Longo et al., 2023) which suggests that healthy eating promotes vagal nerve health and, therefore, the overall health of a person.

Studies have shown that the gut-brain axis plays a role in the etiology of autism spectrum disorders and that probiotics can provide a potential treatment (Feng et al. 2023). For example, Shaaban et al. (2018) conducted a study with 30 autistic children between 5 to 9 years in age. After probiotic supplementation of probiotic strains, the subjects showed

significant improvement in their gastrointestinal microbiota and symptoms as well as the severity of their autism symptoms and behavior. The authors point out the non-pharmacological and relatively risk-free nature of probiotics that makes them particularly suitable to children.

In addition to microbiota, there are studies that have examined the effect of omega-3 polyunsaturated fatty acids on HRV. O'Keefe et al. (2006) found that omega-3 fatty acids significantly decreased coronary heart disease patients' heart rate at rest, accelerated return to normal heart rate post exercise, and increased HRV in the high-frequency band which is associated with parasympathetic nervous system activity mediated by the vagus nerve. Lilleberg et al. (2019) found that fatty acids significantly improved the frequency-domain HRV of renal transplant recipients but did not improve time-domain HRV or resting heart rate. The authors call for additional studies. The articles by Singer (2008) and Christensen (2011) also recommend that further research is conducted to understand how omega fatty acids may increase HRV.

Storybook Educating Children about the Vagus Nerve

The benefits of stimulating the vagus nerve in natural ways have been established in multiple scientific studies. In addition, they are tried and true practices that have been part of mindfulness for centuries. Given the concern for the well-being of young children, it seems important to educate them about the therapeutic and preventative benefits of stimulating the vagus nerve. This should be done in an age-appropriate way.

Stories have always offered entertainment and an escape from reality but they have also served to educate. Tales of all sorts have been used to pass on knowledge to new generations (Crocetti & Barr, 2020). Horst (2015) argues that storybooks could be used much more to help children understand the world around them. Educational stories can be a particularly effective way of conveying scientific knowledge, for example, because they

provide “meaningful, coherent and memorable contexts” (Walan, 2019, p. 35). Furthermore, a narrative can engage children better than a traditional expository text (Crocetti & Barr, 2020). Moreover, science storybooks can support informal science education in the context of homes and act as a catalyst for elaborative discussions on science topics (Haden, 2023).

Stories can be created to not only educate but to influence behavior. Hartling et al. (2010) confirm that narratives, stories, and storytelling are often used in a healthcare and health promotion context. The study by Zhou et al. (2019) showed that stories can be used to improve oral health behaviors in preschool children. After a 2-year intervention, the children in the experimental group that received social stories “performed more toothbrushing steps, spent more time in toothbrushing and were more likely to visit the dentist” than children in the control group who were given standard leaflets as education material (Zhou et al., 2019, p. 419).

A storybook was chosen as the medium for presenting the vagus nerve to children. The short stories offer an everyday context for the information presented and the rhymes facilitate the retention of the advice being offered. The stories provide concrete examples of how the child can stimulate their vagus nerve by themselves. The practices chosen for the storybook are ones that the child is possibly already engaged in or is able to access easily.

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WAKE UP YOUR VAGUS NERVE

Stories for elementary school students

FOREWORD

The vagus nerve is the longest of our cranial nerves, connecting the brain to the heart, lungs, kidneys, liver, spleen, stomach, small intestines, and the muscles in the throat and neck.

Studies have shown that a well-functioning vagus nerve is beneficial for the body and mind. People with high vagal tone have, for example, fewer respiratory, digestive, and cardiovascular problems. In addition, they exhibit reduced anxiety, depression, and reactive behavior. An adaptive vagus nerve is central in coordinating the body's ability to react and recover from stressors, which is directly related to physical and mental well-being
.
The vagus nerve can be stimulated and strengthened in several natural ways such as meditation and movement-based contemplative practices (e.g. yoga and tai chi), exercise, singing, chanting, and humming, cold exposure, massage, laughing, and gut health. All of these elements have been present in mindfulness practices for millenia. They are easily taught and sustained, non-invasive, low cost, low risk, and, therefore, safe for children.

As the benefits of stimulating the vagus nerve are both therapeutic and preventative, I welcome you to explore them with young children as a way of offering them tools that will help them cope with the stresses in life in a healthy way.

BREATHING

There once was a child who was tossing and turning.
Catching some Zs was their deepest yearning.
Alas, they could not fall asleep
no matter how hard they counted sheep.
It was then they heard a faint little sound
even when nobody could be seen around.
Who is it that speaks?, asked the child
from behind two pillows into a large fortress piled.
My name is Wonderer, came the reply.
It was tired and weary, akin to a sigh.
You cannot see me because I reside inside you.
All the way from your brain down to your stomach I run through.
Along the road I pass through the throat, lungs and heart.
My job is to deliver messages as quick as a dart.

Intrigued, asked the child: What messages do you carry?
The reply was: Whatever the brain finds necessary.
There could be a danger that requires some action
like on an icy road almost losing your traction.
Your body gets ready to fight and stay standing
to avoid painfully on the ground landing.
Your heart in this moment beats very fast
but it should not in the fight or flight mode last
because I deliver a new message when danger has ended
and all through the body calm should be extended.
To do my job well I must be strong.
Otherwise, your heart can stay stuck racing all night long.
That is my case, declared the tired child.
Tomorrow at school we have show and tell they nervously smiled.
Even the thought of it makes me very nervous.
Can you offer me some advice -it would be a great service.
There are many easy ways to make me stronger.
Let’s get to work and not wait any longer
because it is tiring for the body to stay so alert
and in the process also the mind gets hurt.
Constantly being overly worried
makes you nervous and so very flurried.
To strengthen the Wanderer a.k.a the vagus nerve
you can simply better your breathing observe.

First, through your nose slowly breathe in.
Keep your head straight forward without lowering your chin.
Then, then through the mouth very slowly breathe out
repeating this a few times will relax you throughout.
To make this more fun you could try blowing soap bubbles,
without even noticing you would be breathing away your troubles.
The child carefully followed the Wonderer's advice
and there was no need for any fancy and costly device.
The child was now peaceful and sound asleep
what an effective method and so incredibly cheap.
And the Wanderer from the deep breathing felt much stronger
and didn't suffer from lack of strength any longer.

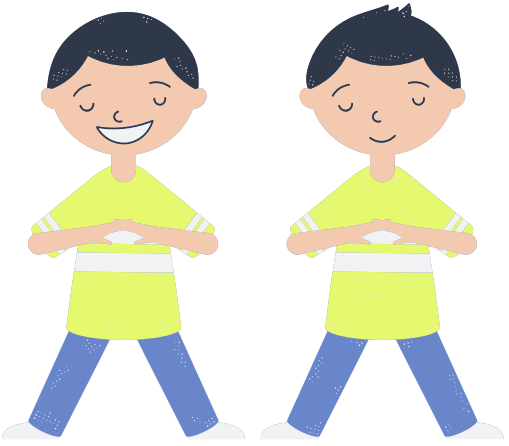
SIMPLE BREATHING EXERCISES

Five-finger breathing exercise

Spread the fingers of one hand apart.
Using the pointer finger of the other hand, trace up you thumb inhaling.
Trace down the thumb exhaling.
Repeat the same steps with the other fingers. Inhaling as you trace the finger up and exhaling as you trace the finger down.

Four squares breathing exercise

Breathing in (inhaling) slowly count to four.
Holding your breath count to four.
Breathing out (exhaling) slowly count to four.
Pausing count to four.
Repeat the steps until feeling calm.



EXAMPLES OF EASY YOGA POSES

to combine with slow breathing

SPHINX

• Lie on your belly placing the forearms on the floor. Lower your chin to the floor and keep your legs together.
• Pressing the forearms to the floor, inhale and lift your head and chest off the floor.
• Hold your breath for a moment and then inhaling lower your head and chest back to the floor.
• Repeat a few times.

COW and CAT

• Place your hands and knees on the floor (table pose).
• Inhaling look up at the ceiling or sky and let your belly sink towards the floor or ground (cow pose).
• Exhaling round your back towards the ceiling and look at your belly (cat pose).
• Alternate between the cow and the cat pose a few times.

TREE

• Standing on one leg bend the other knee and place the sole of your foot on the other leg's inner thigh or calf.
• Focusing your eyes in one spot to help you balance press your palms together over your heart.
• Maintaining your balance inhale and exhale slowly a few times.

EXERCISING

There once was child who was feeling stressed
because the next day they were having a history test.
They kept reading and reading
but were not at all succeeding
in remembering names of great women and men
and what it was they did why, where and when.
Just as the child was all hopeless and giving up,
somebody whispered: You'd better stop
thinking that there is no solution to be found.
I'll tell you how this can all be turned around.
Very surprised, the child looked around,
but in the room nobody else could be found.
Who is it that speaks, inquired the child
wondering if it was their own mind that was running wild.
My name is Wanderer, came the answer very quickly
I am your longest nerve and can stop you from feeling sickly.
For some time you have been stuck feeling anxious and frozen.
Persisting in front of your books is the method that you have chosen
to try to remember all the names and dates
but this way does not seem to be opening your memory's gates.

Answered the child: You are exactly right.
I am to too nervous to remember anything despite using all my might.
Wanderer, can you please offer me some kind of advice
does there perhaps exist some kind of device
that can help me calm my mind
and leave my worries behind.
I am glad to assist you, replied the vagus nerve,
it is exercise that us both can serve.
When running or climbing your heart starts beating faster
and the benefits to your mind come soon thereafter.
It is you exercising that wakes me up for action
and alerts me like a firefighter to react in a fraction.
I message the brain when the exercise has ended
that it is time to return to a state of calm very splendid.
When your heart rate becomes slower,
your level of stress gets lower.
So what you are in essence suggesting
is that I could give my new jump rope a testing.
You can jump, dance, spin or sprint,
shoot hoops, or do an acrobatic stint.
Any kind of exercising keeps me alert and attentive
and in this for you is a big incentive.
When I am kept active,
I can help you be less reactive
by quickly after something stressful restoring calm in your mind
and making sure you are not by your worries confined.

So make sure you have some movement in each day
and that will help in keeping your worries at bay.
This doesn’t mean that all problems from your life will disappear
instead in your mind you will not let them create such a stir.
I like this suggestion and would like to give it a try.
I will take my jump rope and bounce very high
and after an hour return to my history book
and give it another mindful look.

Which of the following kinds of exercise do you enjoy?

Are there additional ways in which you like to exercise?

walking

running

swimming

dancing

hopscotch

jumping rope

minigolf

climbing

bicycling

skateboarding

skating

skiing

sledding

SINGING & LAUGHING

There once was a child who was feeling low.
A friend at the playground had given their self-confidence a blow.
The child had been pondering and ruminating for days
but the mind could not find its way out of the maze
of thoughts that were unhappy and depressed.
I am not feeling well, the child professed.
Right at that moment, the child heard someone announce:
Can I help you back to a state of calm bounce?
Who said that, the child wanted to know
hoping that the person their face would show.
I did, answered the the vagus nerve extended and long,
Can I suggest that you try to sing a song?
The child was surprised by this odd suggestion
and demanded to know what on earth was in question.

I wander from the brain to many places like the throat
that vibrates when you sing and it makes me take note.
I awaken to deliver a message to the brain
that all is well and there is no need to sad and worried remain.
I am stimulated by any kind of humming or song.
So, with no kind of tune could you go wrong.
The child laughed heartily and then replied
I couldn't sing a song even if I tried.
The notes don't come out right
and my singing would not be a delight.
The vagus nerve explained that it did not matter
as long as the throat vibrated the notes could very well scatter.
However, the laughter you just produced is equally effective
if you really feel that your singing is somehow defective.
I do not understand so please explain,
how is it that laughing is good for my brain.
It is because when laughing you also make a sound
which means that the vocal chords in your throat are moving around.
Laughing also makes your heart beat faster
and it activates me, the vagus nerve, to thereafter,
inform the heart to slow down and rest
and the mind as a result feels less depressed.
So, I recommend that you regularly do something enjoyable and amusing.
The giggles and the chuckles will end of up defusing
thinking that is burdensome and heavy
because the vagus nerve is flexible and ready.

I will definitely give laughing a try.
The library has fun books in good supply
or maybe I will see if my cousins are free
and we can sit under a tree
playing board games or telling funny jokes.
that would give our vagus nerve good strokes.
Responded the Wanderer: I like all your plans
and I can already tell you in advance
that stimulating me in such a way
will end up improving your day.

What are some of your favorite songs to sing?

What makes you laugh?

- Why do hummingbirds hum?
- Because they don’t know the words!

- Why did the chicken cross the playground?
- To get to the other slide!

- Where do cows go on a Friday night?
- They go to the moo-vies!

- How do young bees get to school?
- They take the schools buzz!

COLD WATER

There once was a child who was starting a new hobby
and they were trying to sit still while waiting in the lobby
while butterflies fluttered in their stomach
and thoughts racing in their mind created havoc.
The new hobby was very much awaited
and the child was feeling most frustrated
that their excitement was so over the top
and they were hoping to make it quickly stop.
Out of nowhere came a piece of advice:
A splash of cold water would be very nice.
The child looked around but none of the others in the room
had exited their own invisible cocoon.
Every child seemed deep in their own thought
in that case, who had offered the advice the child sought.
Let me introduce myself, said the same voice anew.
I am your vagus nerve a.k.a Wonderer how do you do?

I can feel your excitement that is making you feel so dazed
but I have a remedy that will leave you amazed.
Go to the restroom and with very cold water
splash your face as if you were a playful otter.
How can it help me, asked the child all curious.
Don’t worry this splashing is in no way injurious.
It simply activates, me, the vagus nerve,
and then I will calm and rest in your body and mind conserve
by sending a message to the brain
that there is no reason to be so excited in vain.
You can regularly make use of cold water
if you would like your excitement to last shorter.
You could take a cold shower when you get out of bed
or swim in a pool or lake immersing in the cold water your head.
If feeling brave in a place where there is snow,
into the frozen water vapor you could easily go.
This is a common practice in the country of Finland
and doing so from the sauna makes it feel particularly grand.
The child still feeling overly excited
headed for the restroom and then came back delighted.
The cold water had first made their heart beat very fast
but it did not very long last
because the vagus nerve became activated
and rest and digest to the brain communicated.
The coach invited everyone to enter in through the door
and the child was now feeling much calmer than before.
Thank you, they whispered to the vagus nerve,
how great that you work inside me to my excitement curve.

Would you expose yourself to cold in the following ways?

splashing your face and neck with cold water

taking a cold shower

swimming in cold water

participating in a water balloon battle

sitting in a dunk tank

participating in a snow fight

making a snow angel dressed in a bathing suit

MASSAGE

There once was a child who was feeling ashamed
because of a mistake they had a week ago made.
It might have been in a game, an exam, or a recital.
The actual reason, however, was not really vital.
The child could not bounce back from feeling low,
and the sentiment descended all the way from their head to their toe.
All of a sudden, a voice could be heard.
It wasn’t very clear but instead muffled and blurred.
Can you please speak up? said the child in a manner polite
despite the fact that absolutely no-one was in sight.
I am speaking from inside you, said the voice now louder,
I am sorry that I do not have any magic powder
that could show how I all around your body wander and roam.
As the vagus nerve I am generally to the public known
but you can call me the Wanderer if you like it more.
I have come to help you restore
the feeling that you can manage any obstacles that come your way.
Mistakes you make need not forever in your mind stay.

Let them come but also let them swiftly go.
Here is a trick that I want you to know:
massaging your neck wakes me up
and it's like I into a delivery truck hop
to carry a message to the brain that is still dwelling on the past
that says all is well and now let regrets go at last.
If you give yourself a massage as a regular habit,
I will receive plenty of training and move as fast a rabbit.
When you then face a disappointment big or small
I will inform the brain that all is well in no time at all
and your mind becomes level like a perfectly balanced seesaw
and no problem in life will become the very last straw
that breaks the camel's back
and puts your mind out of whack.
The child, having listened attentively,
found it interesting that massage could preventively
protect their mood
and they felt gratitude
for having inside them a vagus nerve
that was so willing the well-being of the child to conserve.

EASY NECK MASSAGE

• Place two or three fingertips on the back of your neck where the neck meets your shoulders.

• Knead the area as if you were kneading dough.

GUT HEALTH

There once was a child who was feeling quite down.
They couldn't really pinpoint what was making them frown.
Some days they expressed
they were anxious and stressed.
On other days, in contrast, they felt rather sluggish and slow
and thought life had lost its glow.
Then one day at the supermarket in the produce section,
they heard out of nowhere a firm suggestion:
Put a box of blueberries in the cart.
The child wondered out loud: Why would that be smart?
The voice explained in a friendly fashion
that it is good to get your daily ration
of foods that are good for your belly
like fresh blueberries and not the kind in a sugary jelly.
The child asked who was suggesting that the blueberry
was for the health of your gut so necessary.

I am your vagus nerve but you can call me the Wonderer.
I invite you to be for a moment the Ponderer
of what you eat
in any given week.
Are you eating foods like blueberries and yoghurt
that help protect your belly from hurt.
The stomach-friendly bacteria in them are great
it really matters what you put on your plate.
The evidence that the health of your belly affects your mind is very sound
and the same is true the other way around.
How do you know all this, inquired the child.
All this information seems quite interesting and wild.
I am your vagus nerve connecting your brain and gut.
In my time I have already experienced a lot.
In the past weeks you have not felt so well
and now at the grocery store I feel the need to tell
that it is related to what you consistently eat.
What you are feeling is possible to rather easily beat.
I urge you to eat, for example, blueberries, bananas, soybeans,
whole grains, artichokes and also yoghurt by all means.
Try to avoid foods that are sugary or fried,
in the interest of your brain and gut please leave them aside.
The child listened with interest and then replied:
This is something I haven’t yet tried
but I like all the foods that you just listed
and could easily eat them regularly if you insisted.

However, I am also very fond of ice cream
and wonder if you mean
that I cannot eat another scoop again.
If that is so, then,
I am not certain that I can commit to this way of eating.
Of course there is room to be treating
yourself to an occasional sweet or two
as long you don’t revert back to a slew.

How do you like these foods that are good for your stomach?

Brown rice, whole grain bread, bananas, beans, carrots, and broccoli.
What other fiber-rich foods do you like to eat?

Blueberries, strawberries, and blackberries.
What other berries do you like to eat?

Yoghurt, kefir, sauerkraut, kimchi and sourdough bread.
What other fermented foods do you like to eat?