BREATHING AND RESPIRATION

A Behavioral Perspective

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"…the organizing activity of living systems, at all levels of life, is mental activity."
Fritjof Capra (1996)

Psychophysiology

Perhaps the most remarkable, unique, and fundamental feature of all living entities is that they reconfigure themselves (***self-regulate***) based on information (data) they acquire (***learn***), save (***remember***), organize (***perceive***), and use (***behave***). This includes information about their external environment, internal environment, and the outcomes of their own actions (***bio-feedback***). The ***meaning*** of this information, however, is what puts the system into perpetual motion, i.e., provides the ***motivation*** that makes it alive. Concepts like motivation, emotion, attention, perception, memory, reinforcement, and learning, *all behaviorally (operationally) defined constructs*, become essential to a practical understanding of physiology, in this case breathing. In more advanced living systems with sophisticated nervous systems, additional theoretical-constructs become necessarily relevant to achieving a practical understanding of ongoing physiology, e.g., ***cognition*** and ***personality***. Self-reconfiguration is what physiological systems do, that is, they learn based on their environmental (internal and external) encounters, i.e., experience. They are in essence, by nature, ***psychophysiological systems.***

Breathing behavior

Breathing is behavior. This perspective has major implications, one of which is that the vast literature of behavioral science becomes immediately relevant to understanding the how, when, where, and why of breathing for a specific individual. Breathing behaviors (mechanics), e.g., fast breathing, gasping, and aborting the exhale, are programmable (learnable) and are dictated not only by reflexes, but also by programming (learning) principles of physiological reconfiguration, e.g., classical conditioning (associative learning) and instrumental conditioning (reinforcement learning). Understanding these principles is essential to achieving a practical understanding of breathing and its moment-to-moment regulation.

Breathing habits

Breathing habits are learned (programmed) physiological configurations. Habits are not "objects" embedded in physiology that can be physically identified, but are rather descriptions of specific relationships between events, that is, constellations of specific physiological actions (behaviors) and the motivations that drive them, the events (stimuli) that trigger them, the outcomes (reinforcements) that sustain them, and the contexts that may potentiate or inhibit their expression. These constellations are learned physiological configurations that are saved and utilized at specific times and places based on specific learning histories. They are rapidly learned and perpetuated without personal awareness, e.g., maintaining good respiration while talking. Habits are usually learned without awareness, e.g., physical posture, moving the tongue while chewing, breathing while talking. Habits are not "in your mind," they are physiological configurations that may be saved and regulated both centrally and locally.

Habit circularity

All habits are circular, self-perpetuating, for good (friendly) or for bad (vicious). Their circularity makes them tenacious, forever lasting, and potentially insidious. Their circularity is based on (1) embedded motivations that drive them, motivations that are often themselves learned e.g., air hunger, and (2) the outcomes that reinforce them, e.g., air hunger reduction (negative reinforcement) and/or an increased sense of personal control (positive reinforcement). The specific breathing behavior that defines a habit, e.g., "aborting the exhale," may itself establish and perpetuate its own motivation, e.g., the feeling of "not being able to take a larger breath," as a result of the aborted exhale, keeps air hunger in place. Breathing habits, under the right circumstances, can be learned quickly and easily in seconds and self-perpetuated indefinitely, e.g., breathing phobia-driven behaviors.

Behavior analysis

Breathing behavior analysis sorts out the specific components that define a habit (Madden et. al., 2021). The analysis is based on physiological learning (programming) principles and provides for a comprehensive, detailed, and practical mapping of how breathing habits may be compromising respiration and its associated acid-base physiology. Breathing habit components include identification of (1) specific breathing behaviors (e.g., aborting the exhale), (2) specific physiological changes (e.g., hypoxia) and the symptoms (e.g., throat closure) mediated by the behaviors, (3) habit triggers (e.g., task challenges) that regulate the appearance of habits, (4) motivational factors (e.g., breathing claustrophobia, air hunger) that drive the habits, (5) reinforcements that sustain the habits (e.g., feelings of being in control), (6) beliefs and symptom interpretations that support the habits (e.g., self-fulfilling prophecies, "I can't get enough air"), (7) factors that perpetuate vicious circle physiological reconfigurations (e.g., breathing mediated air hunger), and (8) personal histories responsible for learning habits (e.g., experiences with asthma). Breathing habit analysis makes possible discovery of these kinds of behavioral specifics and offers reprogramming (learning) solutions for disengaging, editing, replacing, and learning breathing habits, e.g., "allowing" for alignment of breathing mechanics (behaviors) with respiratory chemistry requirements, that is, external respiration.

Psychophysiological assessment

Breathing assessment requires a psychophysiological perspective. Understanding the dynamics of breathing issues simply based on reference to anatomy (e.g., airway features), fails to account for physiological programming, i.e., learning. Failure to do so is like trying to understand "computer behavior" without reference to its operating system and software applications. "Treating" (fixing) a computer issue by focusing exclusively on its "anatomy" (hardware) overlooks its programming history and its enormous processing capabilities. It ignores the very purpose of its existence and the principles by which it behaves (operates). Computer anatomy (e.g., motherboard), of course, sets the limit of its programmability and can often be a problem itself (e.g., a malfunctioning USB port). Overlooking its programmability, however, would severely limit "clinical" perspective and thus reduce likelihood of effective "treatment" as well as to an increase likelihood of "misdiagnosis" and unnecessary "treatment" (e.g., hard disk replacement). No one denies the importance of "healthy" microprocessors, but to disregard its software would be at best, irresponsible. "Self-programming" (learning) of breathing habits is not just "in your head" or in your "unconscious," it is masterful physiology at work.

"*The relationship between breathing and respiration, mechanics and chemistry, cannot be fully appreciated without understanding the psychological nature of physiology itself. Breathing, like any other behavior, is motivated and changes as a function of its outcomes. Breathing isn't simply mindless automation of physiology to be somehow consciously manipulated in the name of self-help. It is truly so much more than this. Simply manipulating breathing physiology for well-intended purposes, without regard to its psychological nature, does not do justice to the richness and complexity of breathing*." (Litchfield & Reamer, 2022).

Breathing vs. respiration

Breathing and respiration are not the same**.** Breathing is mechanical and respiration is chemical. Breathing (behavior) is programmable, e.g., aborting exhalation, whereas respiration is reflexive, e.g., lower arterial concentrations of carbon dioxide (***$PaCO_2$***) decrease respiratory rate (and thus ***minute volume***) based on autonomic inputs from arterial receptor sites. Breathing mechanics (Behaviors, Table 1) that serve respiration constitute what is known as ***external respiration***, that is, breathing mechanics (behaviors) regulated from breath to breath by brainstem reflex mechanisms. These same mechanics (behaviors), however, also serve many other "objectives" (Reinforcing Outcomes, Table 2), e.g., talking, a sense of control, psychological dissociation (e.g.,

Table 1
BREATHING BEHAVIORS (mechanics)
● Aborting exhalation, taking a breath early
● Accessory muscle breathing (e.g., chest breathing)
● Allowing for transition time, or not
● Assisting the exhale, active exhalation (pushing)
● Assisting the inhale, overriding the reflex
● Controlled and allowed breathing
● Deep and shallow breathing
● Diaphragmatic and abdominal breathing
● Dysponetic breathing (e.g., masseter contraction)
● Effortful breathing, struggling, panting, reaching
● Gasping, during inhalation or exhalation
● Hesitations (e.g., sighing, coughing)
● Holding, breath in or out (delaying exhale or inhale)
● Intentional, conscious, manipulated breathing
● Mouth and nose breathing
● Overbreathing and underbreathing
● Reflexive inhalation
● Relaxed, gentle, easy breathing
● Reverse breathing
● Slow and fast breathing
● Swallowing, gulping, snorting, sniffing

Table 2
BEHAVIORAL OUTCOMES (reinforcements)
● Accessibility to empowering emotions, e.g., anger
● Alteration of states of consciousness
● Avoidance of emotions and feelings
● Disconnection from memories & thoughts
● Dissociation, sense of self
● Effortlessness, ease, freedom
● Escape from physiological distrust
● Familiarity, comfort
● Sense of being control
● Perceptions, e.g., “getting more oxygen”
● Personality changes
● Physical sensations
● Safety, self-confidence
● Relaxation, muscle posture
● Postural changes, static and dynamic
● Reduced sense of vulnerability
● Reduction of air hunger
● Reduction of fear/anxiety/apprehension
● Reduction of pain/discomfort
● Self-reinforcements, e.g., self-fulfilling prophecy
● Useful symptoms, secondary gain

avoidance of memories), and unlocking useful emotions (e. g., anger, for controlling others). The outcomes of breathing habits that serve these other objectives, however, may be at odds with external respiration, that is, they may immediately and profoundly compromise respiration by misaligning breathing mechanics with respiratory chemistry requirements. Understanding breathing as behavior is fundamental to identifying these habits and then editing or replacing them with new ones. Breathing as a behavior includes much more than its obvious role in respiration.

“*The effects of dysfunctional habits can be profound, immediate, and insidious, but rarely is the role of learning and habit formation recognized and even less so effectively addressed. The principal reason for this is that breathing is not usually regarded as behavior*.” (Litchfield, 2010)

Acid-base physiology

Breathing regulates the acid-base physiology of extracellular fluids (e.g., Levitzky, 2007)**.** Breathing, from one breath to the next, regulates pH and electrolyte balance of blood plasma, interstitial fluid, cerebrospinal fluid, and lymph, as described by the ***Henderson-Hasselbalch (H-H) equation***, which says, in its simplest format, that…

$$pH = [HCO_3^-] \div PCO_2$$

The H-H equation specifies that pH of extracellular fluids is equal to bicarbonate concentration $[HC0_3^-]$, ***regulated by the kidneys***, divided by carbon dioxide concentration (PCO_2), ***regulated by breathing behavior*** (mechanics). Changes in the numerator, in response to changes in pH, are slow to start (up to eight hours) and slow to have its ultimate effects (3-5 days), whereas the changes in the denominator are immediate. External respiration (breathing mechanics) is strictly, precisely, and immediately regulated by brainstem reflexes that keep pH within its normal limits, generally 7.35 - 7.45, unless breathing habits get in the way and compromise the equation. This respiratory chemistry, known as ***internal respiration***, can be conveniently described as the ***chemical axis of breathing***.

Reflex regulation

Respiration is reflex-regulated by extracellular chemistry, i.e., pH, PO_2, and PCO_2 (e.g., Levitzky, 2007)**.** External respiration, i.e., breathing behaviors (mechanics) that stabilize and maintain the chemical axis within its optimal window, is regulated by a medullary reflex center, the dorsal respiratory group (DRG), that is responsive to (1) arterial blood plasma changes in pH (***pHa***), partial pressure arterial carbon dioxide (***$PaCO_2$***), and partial pressure arterial oxygen (***PaO_2***) and (2) cerebrospinal fluid changes in pH and PCO_2 (Levitzky 2007). Breathing habits can very quickly and easily disturb this delicate balance. "*The differing melodies of breathing mechanics must ultimately play the music of balanced chemistry*" (Litchfield 2010). Chemistry, however, is not regulated simply based upon the nature of the mechanics themselves. Mouth breathing, for example, often portrayed as a villain of optimal respiratory regulation in breathwork folklore, although undesirable, does not dictate respiratory chemistry. Mouth breathing is correlated with compromised chemistry for psychophysiological reasons, but is not physically causative as will be explained later.

Mechanics and chemistry

Reflexive breathing aligns mechanics with chemistry (Litchfield, 2003, 2010). Alignment normally takes place in accordance with H-H equation requirements, despite continuous and sometimes radical variations in breathing mechanics, such as during talking. Breathing mechanics do so by regulating ***minute volume*** (breathing rate and depth) and thus alveolar partial pressure CO_2 (***$PACO_2$***), which determines arterial CO_2 concentration (***$PaCO_2$***) based on equilibration of pulmonary capillary PCO_2 with alveolar PCO_2. Breathing habits can immediately alter alveolar PCO_2 ($PACO_2$) and misalign mechanics with chemistry requirements, that is, PCO_2 concentration may be either too high or too low, thus significantly disturbing acid-base physiology, pH as per the H-H equation. Alignment means that breathing mechanics are synchronized with H-H equation requirements to maintain healthy acid-base regulation regardless of other concurrent breathing "objectives," e.g., serving respiratory chemistry while talking at the same time. Proper acid-base regulation is fundamental to healthy ***physical*** (e.g., hand-eye coordination), ***emotional*** (e.g., anxiety), ***cognitive*** (e.g., ability to focus), and ***behavioral*** (e.g., test-taking) functioning.

"*Optimal respiratory health means maintaining a stable chemical axis of breathing wherein internal respiratory requirements are immediately and expeditiously addressed, despite the highly variable acrobatics of breathing mechanics during daily life that may be serving us in many other important ways, such as talking.*" (Litchfield & Reamer, 2022)

Overlooking chemistry

Respiratory chemistry is typically overlooked by practitioners who guide their clients in the application of breathing techniques in the name of better health and performance. Breathing practices typically focus on what is perceived to be "good" and "bad" mechanics, e.g., diaphragmatic vs chest breathing, with no attention paid to respiration and its chemistry. The consequence is misguided breathing self-help techniques taught by practitioners and learned by laypeople everywhere. Practicing misguided and uninformed breathing techniques can also set the stage for learning breathing habits that compromise respiration and acid-base balance. Examples of this are described later. The following words describe the status quo.

"*Millions of people from around the world include breathing learning interventions in one way or another in their professional and/or personal lives for a multitude of reasons, e.g., relaxation. Most of them, however, focus exclusively on mechanics of breathing (external respiration), e.g., slow breathing, without understanding and addressing their profound impact on the chemistry of respiration (internal respiration), e.g., acid-base regulation (pH) of extracellular fluids (e.g., blood plasma*). (Litchfield & Reamer, 2022).

Misalignment

Learned breathing habits often misalign mechanics with chemistry. Habits may disconnect breathing from the brainstem respiratory reflexes that normally keep the H-H equation balanced, leading to changes in carbon dioxide concentration (PCO_2) that are either too high (***hypercapnia***) or too low (***hypocapnia***). Learned

underbreathing leads to ***behavioral HYPERcapnia***, partial pressure arterial carbon dioxide ($PaCO_2$) that is too high (>45 mmHg), resulting in ***respiratory acidosis***. Learned ***overbreathing*** leads to ***behavioral HYPOcapnia***, $PaCO_2$ that is too low (<35 mmHg), resulting in ***respiratory alkalosis***. A balanced chemical axis of breathing (35-45 mmHg) is ***EUcapnia***, a normal $PaCO_2$ range in healthy people. Surprisingly to many, however, behavioral hypercapnia (PCO_2 excess), i.e., habits involving underbreathing, is rarely observed (in otherwise healthy people), whereas behavioral hypocapnia is common. This difference is easily accountable from a psychophysiological perspective. That is, the likelihoods of the formation of specific kinds of habit configurations, e.g., underbreathing habits, depend upon the nature of their components and how they are arranged, e.g., behaviors, triggers, motivations, states, outcomes, beliefs, and contexts.

Behavioral hypocapnia

The impact of behavioral hypocapnia on physiology is amazingly comprehensive (e.g., Levitzky, 2007; Thomson et. al., 1997). It quickly leads to fundamental and widespread physiological changes. These physiological changes can be ***profound and immediate***, e.g., up to a 50% reduction in cerebral blood flow in a matter of seconds leading to cerebral hypoxia and hypoglycemia that significantly reduce ability to focus, concentrate, think, and remember. This vascular compromise is further exacerbated by an increase in hemoglobin's affinity for oxygen, as per the Bohr effect (a shift in the oxyhemoglobin dissociation curve to the left), that is, oxygen is less readily distributed. These changes can also be ***subtle and long-term***, e.g., compromised bicarbonate reclamation and regeneration that attenuate acid buffering in the blood plasma. Many of the myriad physiological changes, as a result of compromising the precisely orchestrated relationship of mechanics with chemistry, are listed in Table 3 below (Litchfield & Reamer, 2022).

Symptoms and deficits

Hypocapnia symptoms and deficits are far reaching, even extraordinary (Fried, 1987; Laffey & Kavanagh, 2002). They can be ***immediate*** (e.g., dizziness and disorientation), ***long-term*** (e.g., fatigue), ***dramatic*** (e.g., fainting), ***subtle*** (e.g., reduced reaction time), and ***insidious*** (e.g., shifts in self-esteem). They ***can trigger*** (e.g., headache), ***exacerbate*** (e.g., anxiety), ***perpetuate*** (e.g. nausea), and/or ***cause*** a wide variety of ***emotional changes*** (anxiety, anger), ***cognitive changes*** (attention, learning), personality changes (aggressiveness), ***performance changes*** (public speaking, test taking, athletics), and ***physical changes*** (tetany, vomiting, hypoglycemia) that may seriously impact health and performance. These outcomes can be devastating (e.g., anger episode, panic attack) and life-changing, outcomes that are usually attributed to other causes by both professional and lay people alike. Many of these symptoms and deficits are listed in Table 4 below (Litchfield & Reamer, 2022).

Statistics

Statistics associated with behavioral hypocapnia are impressive. It is estimated that 60% of the ambulance runs in the largest US cities can be attributed to acute symptoms brought on by learned breathing behaviors that compromise acid-base physiology (Fried, 1999). Surveys suggest that up to 25% of the general population may be suffering the effects of learned dysfunctional breathing (Fried, 1999). Interfering with PCO_2 regulation can severely compromise both health and performance.

Interactions

Hypocapnia interacts with unrelated conditions and disorders. Behavioral hypocapnia not only causes symptoms and deficits, but can also trigger, exacerbate, and perpetuate symptoms brought on by other causes, e.g., nausea during pregnancy. Hypocapnia symptoms may also be added to the mix of symptoms originating elsewhere and mistakenly identified as having the same etiology. Both headache and high blood pressure, for example, might both be mistakenly attributed to stress, when in fact headache may be the result of learned overbreathing behavior in response to stress, leading to hypocapnia and its associated cerebral hypoxia and hypoglycemia. Table 5 (Litchfield & Reamer, 2022) is a list of disorders, conditions, and complaints often associated with dysfunctional breathing habits.

Table 3: Hypocapnia - physiological effects

- Antioxidant reduction
- Bicarbonate deficiency (long-term kidney effect)
- Bronchial constriction (airway resistance)
- Calcium migration into muscle cells (fatigue, spasm)
- Cerebral excitatory and inhibitory disturbances
- Cerebral hypoxia, hypoglycemia, ischemia
- Cerebral vasoconstriction (increased pH)
- Compromised O2 distribution (hemoglobin chemistry)
- Compromised nitric oxide distribution (hemoglobin chemistry)
- Coronary (vascular) constriction
- Dishabituation and habituation (CO2 set point?)
- Gut smooth muscle constriction
- Ionized magnesium reduction (tetany and cardiac compromise)
- Hemoglobin, compromised O2 and NO delivery
- Hypokalemia (potassium deficiency)
- Hyponatremia (sodium deficiency, long-term effect)
- Increased neuronal excitability & contractility
- Increased overall vascular resistance (smooth muscle constriction)
- Myocardial electrophysiology disturbances
- Neuronal acidosis (lactic acid)
- Plasma alkalinity, effects on endothelial NO production
- Reduced ocular blood flow
- Reduced lung compliance
- Reduced splanchnic organ perfusion (hepatic and renal arteries)
- Sodium and potassium migration into cells (excitability)
- Stress hormone release (ACTH)
- Thrombosis, platelet aggregation
- Tissue inflammation

From Litchfield & Reamer (2022)

Table 4: Hypocapnia - symptoms and deficits

- Abdominal: nausea, vomiting, cramping, bloatedness
- Autonomic-stress: acute fatigue, chronic fatigue, headache, muscle pain, weakness
- Cardiovascular: palpitations, tachycardia, arrhythmias, angina symptoms, ECG abnormalities
- Cognitive: attention deficit, learning deficits, poor memory, brain fog, inability to think
- Consciousness: dissociation, state change, dizziness, fainting, confusion, hallucinations
- Emotional: anxiety, anger, fear, panic, phobia, apprehension, worry, crying, low mood
- Movement: diminished coordination, reaction time, balance, perceptual judgment
- Performance: sleep apnea, insomnia, anxiety, rehearsal, focus, endurance, muscle function, fatigue, pain
- Peripheral: tingling, numbness, trembling, twitching, shivering, coldness, sweatiness
- Psychological: shits in personality, self-esteem, memory, emotion, thought
- Respiratory: shortness of breath, airway resistance, bronchial constriction, asthma symptoms
- Sensory: blurred vision, sound seems distant, reduced pain threshold, dishabituation, dry mouth
- Skeletal (muscles): tetany, hyperreflexia, spasm, weakness, fatigue, pain, difficult to swallow, chest discomfort
- Smooth (muscles): cerebral, coronary, bronchial, gut, ocular, splanchnic, and placental vasoconstriction

From Litchfield & Reamer (2022)

Table 5: Hypocapnia – exacerbation of health issues and complaints

- Behavioral: performance issues, speech, singing, task challenges
- Cardiovascular: angina, heart attack, arrhythmias, ECG abnormalities
- Chronic pain: injury, disease, systemic inflammation
- Cognitive: learning disabilities, ADD, ADHD
- Drug efficacy: shifts in pH and electrolyte balance alter absorption
- Emotional: anger, phobias, panic attack, anxiety, depression
- Fitness issues: endurance, muscle strength, fatigue, altitude sickness
- Gastric: irritable bowel syndrome (IBS), non-ulcer dyspepsia
- Neurological: epilepsy
- Neuromuscular: repetitive strain injury (RSI), headache, orthodontic
- Pregnancy: fetal health, premature birth, symptoms during pregnancy
- Psychological: trauma, PTSD, drug dependence
- Psychophysiological disorders: headache, chronic pain, hypertension
- Respiratory: asthma, emphysema, COPD
- Sleep disturbances: apnea
- Unexplained conditions: fibromyalgia, chronic fatigue
- Vascular: hypertension, migraine, ischemia, hypoglycemia, ocular, placental vasoconstriction

From Litchfield & Reamer (2022)

Mistaken diagnoses

The effects of behavioral hypocapnia are usually mistakenly attributed to other causes. Most practitioners, unaware of symptoms and deficits brought on by breathing habits, almost necessarily confuse them with symptoms indicative of other disorders. Herbert Fensterheim, a famed psychoanalyst, puts this into perspective for practitioners in the mental health professions, as follows:

"*Given the high frequency of incorrect breathing patterns in the adult population, attention to the symptoms of hyperventilation [overbreathing] should be a* ***routine part of every psychological evaluation, regardless of the specific presenting complaints****. Faulty breathing patterns affect patients differently. They may be the central problem, directly bringing on the pathological symptoms; they may magnify, exacerbate, or maintain symptoms brought on by other causes; or they may be involved in peripheral problems that must be ameliorated before psychotherapeutic access is gained to the core treatment targets. Their manifestations may be direct and obvious, as when overbreathing leads to a panic attack, or they may initiate or maintain subtle symptoms that perpetuate an entire personality disorder. Diagnosis of hyperventilatory [overbreathing] conditions is crucial.*" (Fensterheim, 1994)

Misinterpretations

Misinterpretation of hypocapnia symptoms and deficits is a significant issue. It easily leads to faulty clinical diagnoses, treatments, and personal interpretations that can have devastating and long-lasting effects.

CASE EXAMPLE #1: A Meckenzie trained Diplomate in mechanical diagnosis and therapy (Campbell, 2014), reported a case of a patient with central canal stenosis in the cervical spine (neck) as a result of an automobile accident. Her patient had had previous surgery for this condition and was now being considered for yet further surgery based on a continuance of the same symptoms, including trembling, tingling, numbness in the feet and forearms, and vision changes. The neurosurgeon referred his patient to Campbell for further evaluation before making his final decision. Campbell notes that had she not been previously trained in breathing behavior analysis, she would have considered these symptoms to be normal, given the previous diagnosis. Based on the same thinking as that of Fensterheim, described in the quotation above, she decided to test her patient for a possible breathing habit that may have been mediating the symptoms.

She tested her patient by instructing her to alternate between sitting with her head erect and her head moved back. Moving the head back narrows the canal and would be expected to put pressure on the spinal cord and trigger the stenosis symptoms reported. When the head went back, as would be expected, the symptoms appeared within a very short time. Campbell, however, was also monitoring the patient's ongoing $PetCO_2$ with a CapnoTrainer, used for identifying breathing habits and learning new ones. She noticed that PCO_2 concentration began to decrease radically at the moment the head went back (20 - 22 mmHg), i.e., severe hypocapnia. She then coached the patient to increase PCO_2 by taking smaller and gentler breaths. The symptoms, all of them, disappeared in a matter of minutes. (Note that it takes time to restore normal PCO_2 concentrations.) Coaching the patient once again to lower PCO_2 brought back the symptoms in less than a minute. Subsequent alternating between hypocapnia and eucapnia, triggered or abated symptoms accordingly. Surgery plans were cancelled.

Interestingly, the patient herself continued to want surgery. It took time for her to appreciate that she had learned a breathing habit that was mediating her symptoms. Her breathing habit had become a doorway into an alternative sense of self, a personality that engendered more support from others. That is, the symptoms had become important to her as a basis for ***secondary gain***. As is described later in this chapter, this is an example of a Type-3 breathing habit, wherein hypocapnia symptoms themselves triggered troublesome learned emotions, cognitions, and behaviors. Fortunately, however, in the end, the patient learned to disengage the habit and eliminate the symptoms. Campbell has for a long time now included breathing behavior assessment as a basic service in her five physiotherapy clinics.

CASE EXAMPLE #2: David Beales (personal communication, 2024), a UK physician, reported a case of a patient who was diagnosed with a cardiac condition by a prominent consulting cardiologist, based on symptoms that included nonspecific upper chest pain, tingling in the hands and feet, dizziness, and stomachache. The electrocardiogram showed minor changes, none of which suggested serious compromises. The symptoms appeared during times of stress, which unfortunately included while driving his automobile. The cardiologist contacted the motor vehicle authorities and his driver's license was revoked. Subsequently, Beales suggested that his breathing behavior be assessed while driving. The results clearly showed that "driving" was a trigger for a breathing habit that led immediately to serious hypocapnia (25 mmHg). The patient learned to disengage the habit wherein the PCO_2 concentrations while driving normalized (eucapnia, >35 mmHg). His symptoms disappeared and his driver's license was reinstated. Interestingly, however, upon learning the outcomes of the behavioral applications, the cardiologist nevertheless insisted upon his original diagnosis.

Habit triggers: stimulus control

Stimulus control is a basic component of habit configuration. That is, all habits are regulated by triggers, that is, stimuli of many kinds. Stimuli are events sensed or perceived by physiology, "experiences" that trigger learned responses. Based on specific learning histories, they bring about the right behaviors (responses) at the right place and at the right time, very precisely. These triggers can be external (e.g., visual), visceral (e.g., pain), proprioceptive (e.g., movement), state specific (e.g., feeling disoriented), emotional (e.g., fear), cognitive (e.g., a thought or memory), social (e.g., intimacy), or personal (e.g., loss of self-confidence). Examples include lying down to go to sleep, beginning to initiate a sport, seeing one's supervisor, taking a test, beginning to play the piano, waiting to hit a golf ball, feeling stressed, detecting an allergen in the air, worrying about getting enough air, picking up a cigarette, pressure on the diaphragm, making a new acquaintance, driving in traffic, feeling angry, being presented with a crisis, resting, feeling a symptom, waiting for your doctor, sitting down at a meeting, feeling apprehensive, and numerous others. Learning, modifying, and unlearning habits necessarily involve identifying and editing stimulus control. Here are two examples of breathing habit stimulus control.

CASE EXAMPLE #1: A professional counselor, also a yoga instructor, reported that he had been suffering with chronic hypertension for more than ten years, with diastolic levels above 95 mmHg. Having measured his blood pressure for many years within minutes of completing his yoga sessions, and having found no significant changes, he had concluded that yoga had no effect on his blood pressure. Taking note during a breathing behavior analysis session that his diastolic pressure was 98 mmHg and that he was severely hypocapnic (24 mmHg), he was asked to do a yoga session demonstration. Within five minutes, he was eucapnic (41 mmHg) with a diastolic pressure of 74 mmHg. Within two minutes of the completion of his yoga demonstration, however, he became significantly hypocapnic (27 mmHg) with a diastolic pressure of 96 mmHg. He had mistakenly assumed that taking his blood pressure immediately following his yoga sessions was an appropriate test of the effects of yoga. He was simply unaware of his breathing habits and how they immediately compromised or optimized respiration based on specific triggers. This is an excellent example of stimulus control and its immediate and precise regulation of breathing behaviors.

CASE EXAMPLE #2: A "breathworker" reported that she had had an injury to her chest some years back and that since then, when she was in closed unventilated spaces such as her own home, she felt disoriented with air hunger. After stepping outside or opening the windows, however, the symptoms dissipated within minutes. Her conclusion was that her injury had somehow compromised her breathing such that oxygen in poorly ventilated buildings was inadequate. She thus kept her windows open at home. Her theory was supported by others who recommended a chiropractic adjustment based on how her injury may have anatomically compromised her breathing. A breathing behavior analysis revealed that when feeling claustrophobic, such as walking into her home, she would immediately take control of her breathing and begin to overbreathe, but upon opening the windows she let go of control and allowed reflex regulation to reassert itself. Her misguided belief systems and symptom interpretations provided a supportive context for the dysfunctional habit.

Habit outcomes: reinforcements

Reinforcement is a basic component of habit configuration. The outcomes of breathing behavior establish and sustain habits. Learning (programming) based on ***behavioral outcome contingencies*** is known as ***instrumental conditioning***, a learning paradigm described in great detail as part of an immense experimental literature that ranges from simple cells to humans. Instrumental conditioning is fundamental to understanding how breathing habits are established and perpetuated. Outcomes that ***increase the probability*** of a breathing behavior are ***reinforcements***, of which there are two basic types. A ***positive reinforcement*** is the ***onset of*** the event that increases the likelihood of a behavior, e.g., aborted exhalation ***provides*** "a sense of control." A ***negative reinforcement*** is the ***offset of*** an event that increases the probability of a behavior, e.g., aborted exhalation ***removes*** (or reduces) "fear." As simple as this may seem, the reality of it becomes complex. As is often the case, "the devil is in the details." Breathing behavior analysis is about identifying these details and then reconfiguring them in a more productive way.

There are many kinds of outcomes that reinforce breathing behaviors that compromise respiration, specifically behaviors that may lead to hypocapnia. These reinforcements range from outcomes directly associated with breathing itself (e.g., air hunger reduction) to outcomes completely unrelated to breathing (e.g., avoidance of a traumatic memory). Examples of reinforcement range from the obvious to the unexpected. An obvious one is air hunger reduction that reinforces "pushing exhalation" (getting it done quickly) or aborting exhalation (getting it done earlier). An unexpected one, to both client and practitioner, was "avoiding the feeling of heartbeat" through the unconscious use of breathing accessory muscles, i.e., so-called chest breathing, to obscure the otherwise disturbing sensation of heartbeat, all at the expense of decoupling mechanics from chemistry.

Examples of categories of positive reinforcements (Table 2) for learning dysfunctional breathing behaviors include ***access to emotions*** (e.g., anger for social control - cerebral disinhibition), ***symptoms*** (e.g., headache for secondary gain - cerebral hypoxia and hypoglycemia), ***state changes*** (e.g., disorientation for a different sense of self - neuronal compromise, lactic acidosis), ***behaviors*** (e.g., easier verbal expression), ***feelings*** (e.g., sense of control, freer, safer), and ***cognition*** (e.g., positive self-talk). Examples of categories of negative reinforcements (Table 2) include ***escape from*** or ***avoidance of emotions*** (e.g., air hunger, anxiety, fear), ***cognition*** (e.g., negative self-talk), ***memories*** (e.g., traumas), and ***behaviors*** (e.g., listening to a teacher). The source of one very important mega-reinforcement is ***mistrust*** of one's breathing, invariably supported by the belief that "breathing must be done," manipulated rather than simply allowed. "Taking control" of breathing resolves the issue of distrust, but unfortunately embraces the essence of the origin of many dysfunctional habits. Belief systems often unwittingly support these habits, including prevailing breathwork programs that may actually teach them.

Habit motivation

Motivation is a basic component of habit configuration (Schachtman & Reilly, 2011). Although, basic motivations, e.g., fear, are built into physiology by virtue of its hardware (anatomy), they are continuously edited, i.e., reprogrammed, based on interactions of physiology with its environment and itself. Motivation, e.g., air hunger, can be easily and very rapidly learned based on the principles of classical (Pavlovian) conditioning, associative learning where one stimulus predicts another, that is, a second stimulus in time is contingent on the occurrence of a first stimulus. THE SECOND STIMULUS, the ***UnConditioned Stimulus*** (the **UCS**) triggers a reflex (or a previously learned response), an ***UnConditioned Response*** (the **UCR**), e.g., specific emotions, hormone secretions, or smooth muscle contractions. The FIRST STIMULUS, however, prior to the conditioning (learning), does not. By virtue of the informative relationship, however, the first stimulus becomes a **Conditioned Stimulus** (the **CS**) wherein it now elicits a **Conditioned Response** (the **CR**), a response similar to the unconditioned response (the UCR) elicited by the second stimulus, the unconditioned stimulus (the UCS).

CASE EXAMPLE: A university track star went for surgery on his ankle and was traumatized during his recovery from general anesthesia. During his initial moments of consciousness, he struggled "to get his breath" while experiencing extreme air hunger and panic. Immediately thereafter, he had been unable to compete for many months. Subsequently, during breathing behavior analysis, he discovered that he had learned a phobia embedded in the context of his breath. Effortful breathing elicited intense fear and air hunger upon starting to run, leading almost immediately to hypocapnia and an inability to perform. His symptoms were misinterpreted by both him and his healthcare provider. Breathing behavior analysis, however, provided him with behavioral solutions, including ***desensitization*** to "breathing effortfulness" wherein conditioned motivation (air hunger and panic) was extinguished and thus the reinforcement for his overbreathing (air hunger and fear reduction) necessarily disengaged. Part of this desensitization also included ***negative practice*** for learning to engage/disengage behavioral hypocapnia at will, both learning protocols to be described later.

Motivation and reinforcement are inextricably connected. Altering motivation alters the source of reinforcement. Extinction (unlearning) of fear or air hunger at the end of the exhale, for example, eliminates "fear or air hunger reduction" as a reinforcement for "aborting exhalation." It also provides for self-discovery, awareness learning, of the inhalation reflex during the transition time between exhale and inhale, setting the stage for the emergence of a powerful new experience that reinforces "allowing the reflex" - a sense of somatic trust that dissolves motivation for vigilance and doubt. This new habit configuration is almost necessarily accompanied by a new belief system regarding breathing, new interpretations of symptoms mediated by breathing, and a new somatic relationship between person and body (to be discussed later). Finding new reinforcements for new behaviors is fundamental to editing, disengaging, and establishing breathing habits.

Motivation and reinforcement, of course, also operate on a cognitive level where what people say to themselves, their beliefs about breathing and interpretations of their symptoms, serve as powerful self-reinforcements, or punishments which reduce the probability of behaviors. Social motivation and reinforcements guide people as to what they may or may not learn in regard to their physiologically programmed breathing habits. Interviewing people about their breathing is client-centered, where close attention to what clients say, based on questions that encourage self-observation, is crucial.

Dysfunctional breathing habits

Breathing habits are dysfunctional when they compromise health and performance (Litchfield, 2006). This could be physiological (e.g., electrolyte balance), psychological (e.g., problem solving), and/or behavioral (e.g., landing an airplane). Three kinds of dysfunctional breathing habits can be defined based on their locus of stimulus control:

TYPE-1 dysfunctional habits consist of reinforced breathing behaviors, triggered by specific experiences (stimuli), that compromise function, e.g., “worry about oxygen” triggers (i.e., has stimulus control over) “doing the breathing” reinforced by “feeling in control,” a sequence of events leading to behavioral hypocapnia.

TYPE-2 dysfunctional habits consist of breathing behaviors wherein they themselves serve as interoceptive experiences that trigger (i.e., exercise stimulus control over) learned emotions, cognitions, and actions (other behaviors) that compromise function, e.g., (1) the [experience] of fast breathing triggers a learned emotion, conditioned fear, which compromises test taking, (2) the [experience] of nasal breathing triggers a learned cognition, thoughts about getting enough air, which motivates overbreathing, and (3) the [experience] of chest breathing triggers a learned action (behavior), masseter contraction, which results in headache. Type-2 habits are about breathing experiences themselves that regulate (trigger) yet other behaviors and habits.

CASE EXAMPLE, Type-2 breathing habit: A competitive athlete became fearful of doing exercise because it triggered unwanted physical symptoms and emotions. She had thus discontinued her workouts altogether for the previous six months and had gained weight as a result. She had become afraid of even going on hikes with friends. She was tested for changes in PCO_2 concentration on an exercise bike. Sitting on the bike seat while peddling minimally had no impact on PCO_2 concentration. However, upon increasing the workload from light to moderate her PCO_2 concentration immediately plummeted from eucapnic concentrations (above 35 mmHg) to severe hypocapnic concentrations (23-25 mmHg). All of her symptoms immediately appeared. Upon reducing the peddling workload, however, within two minutes her PCO_2 was restored to eucapnic levels and her symptoms disappeared entirely. She repeated the peddling pattern, light vs moderate, with same outcomes. The experience of “effortfulness” itself triggered taking larger breaths in the name of “getting more oxygen.”

She learned to disengage the habit through ***negative practice***, a behavior therapy technique, where she took ownership of the habit by learning to engage and disengage the habit at will. The symptoms never reappeared and she lost her fear of effortful physical activities. It is significant to note that although breathing training was a part of her own work as a physiotherapist, it was entirely new to her that athletes could learn breathing habits that mediate symptoms and compromise performance. Failure to identify “physical activity” as a habit trigger for a learned breathing behavior had prevented her from identifying the cause of her symptoms and finding an effective solution. A breathing behavior analysis, however, provided for both.

TYPE-3 dysfunctional habits consist of breathing behaviors that mediate symptoms that themselves exercise stimulus control over (i.e., trigger) learned emotions, cognitions, and actions (other behaviors) that compromise function, e.g., (1) “dizziness” triggers a learned emotion, fear of losing control, (2) “attention deficit” triggers a learned cognition, self-deprecating thoughts about deficits, and (3) airway resistance (bronchial constriction) triggers a learned action (behavior), taking larger breaths (which exacerbates hypocapnia) all three of which compromise performance, including self-confidence. Type-3 habits are about how symptoms, brought on by breathing itself, trigger (regulate) other behaviors or habits embedded in a yet larger multi-habit configuration, a ***breathing pattern***.

CASE EXAMPLE, Type-3 breathing habits: Here is a fictitious, but all too common, example. In social situations, during adolescent times, a person who is nervous learns to take charge of breathing while talking, a breathing behavior that provides for an improved sense of personal control. This manifests itself by speaking as long as possible before taking a recovery breath. The consequence is air hunger that motivates taking much larger breaths that leads to overbreathing and cerebral vasodilation and thus exacerbation of anxiety (cerebral disinhibition), inability to focus, and memory impairment. The symptoms are misinterpreted by both the speaker and listeners. The speaker feels progressively less adequate, rapidly losing self-confidence, and listeners progressively less impressed. The symptoms set the stage for learning agoraphobia.

Breathing patterns

Constellations of habits form breathing patterns. Breathing habits and their components, along with related habits, often interact so that understanding the dynamics of any one of them requires a more comprehensive perspective, one that also includes the context in which they operate, e.g., belief systems. Breathing patterns are interconnected habits, chained behaviors, powerful relationships embedded in attitudes, personality, and lifestyles. Types 1, 2, and 3 breathing habits, for example, are very often simultaneously issues for clients, one habit triggering the next. Here is an example:

Type-1 habit: A COVID mask triggers air hunger that motivates faster breathing that is reinforced by both feelings and thoughts about getting more oxygen. ***Type-2 habit***: "The experience of faster breathing" triggers (a) anxiety (emotion) and (b) negative self-critique about breathing (cognition) that together motivate "taking slower larger breaths" reinforced by (a) sense of control, (b) anxiety reduction, and (c) "doing breathing the right way" (a self-reinforcement). ***Type-3 habit***: The larger breaths, however, result in hypocapnia and its associated symptoms including dizziness, disorientation, headache, and nausea that motivate hypochondrial behavior and social manipulation reinforced by its associated secondary gain (attention from others). Secondary gain ties together the three habits into a vicious circle pattern, where headache, nausea, and other outcomes are blamed on the mask and/or are connected with "long-COVID" by both client and practitioner.

Impersonal (unconscious) learning

Most habits are not intentionally learned and engaged. Consider the unique physical posture and mannerisms that everyone learns, dictated by personal experience within specific cultural contexts, e.g., in Scandinavian countries, the frequent audible sighing at the start of a breath while talking. Sighing, during breathing, is not intentionally taught nor learned. If it weren't for the rest of the world, the "Scandinavian sigh" might be considered as "natural," a respiratory reflex of some kind. What is fundamentally "natural," however, is that people learn breathing habits, that physiology is unintentionally and unconsciously reconfigured based on experience. When a habit is indeed acknowledged, however, the question remains as to "who" or "what," does the learning. The answer is important because it dictates the learning strategies to be recommended and/or implemented for disengaging a habit and learning new ones.

If a "person," e.g., John Smith, rather than John's physiology is considered to have unconsciously learned a breathing habit, John's "unconscious" is necessarily identified as the learner. Delegating learning to the "unconscious" shrouds breathing habits in a place of psychological deadspace (mystery) and overlooks the programmability of physiology itself; it separates "mind" from "body." This frame of reference serves to keep physiology separate from behavioral principles wherein the symptoms mediated by a breathing habit may instead be attributed to a "disorder" that requires "treatment," e.g., asthma becomes the sole culprit of a symptom, without reference to possible physiological programming that may have been unwittingly learned in response to asthma, e.g., gasping. It leads to an exclusive focus on the "person" and what *they need to learn*, i.e., ***personal learning***, without understanding and including what the *physiology itself needs to learn* concomitantly with the "person" or even independently of the "person," i.e., ***impersonal learning***. Practically speaking, this means a partnership, person and body, and the development of a psychophysiological awareness. Breathing behavior modification thus requires both kinds of learning, personal (e.g., learning new beliefs) and impersonal (e.g., extinction of air hunger motivation).

Habit generalization

Habit (stimulus) generalization is a fundamental programming principle. Stimulus control, associated with specific breathing habit triggers, generalizes. That is, stimuli similar to the original ones associated with the acquisition of the habit, also regulate the habit. Stimulus generalization makes practical applications of habits possible, both in the case of classical conditioning (e.g., wearing anything resembling a mask triggers air hunger) and instrumental conditioning (e.g., sitting in examining chairs similar to dental chairs, trigger "doing the breathing" reinforced by an improved sense of control). Significantly, however, in the case of human physiological programming, stimulus generalization occurs not only in respect to differing versions of the original stimuli, but can also occur based on semantic similarities, i.e., metaphors. Here is an example:

EXAMPLE: A patient suffered from asthma symptoms when socially challenged. Historically, based on serious asthma challenges, she had learned to "reach for more air," a breathing behavior reinforced by an improved sense of control (instrumental conditioning) and supported contextually by her misguided belief system about breathing and her faulty interpretations of breathing-mediated symptoms. Her "sense of struggle" during asthma episodes, by virtue of the reinforced breathing behavior, connected the associative dots between "struggle" and compromised PCO_2, thus providing for classical conditioning of respiratory reflexes, i.e., "sense of struggle" itself, now regardless of its source, triggered bronchial constriction, a conditioned reflex.

Stimulus control, associated with "sense of struggle during asthma episodes," generalized by metaphor to a "sense of struggle during social challenges," thus triggering classically conditioned bronchial constriction (increased airway resistance) that motivated "reaching for more air." The habit became self-perpetuating, independent of its original history. The hypocapnia symptoms, e.g., increased airway resistance, triggered by "social challenges," were mistakenly attributed to asthma. The possible role of programming history, i.e., learning breathing habits based on having suffered asthma, was entirely overlooked. One possible solution was medication, the other reprogramming, i.e., disengaging the breathing habit. Medication, as it turned out, was not the preferred solution.

State-dependent learning

State dependent learning sets the stage for chronic overbreathing habits. When neurophysiology is compromised by breathing, awareness changes, including perception of the environment and sense of self. Dissociation, an altered state of consciousness brought about by reduced cerebral blood flow, is an all-encompassing outcome that may titrate psychological change, for good or bad, much as do psychoactive drugs. One outcome of dissociation is its effect on stimulus generalization, that is, what you learn while in one psychological state may not transfer (i.e., generalize) to another, a phenomenon known as ***state-dependent learning***. What may be learned in a dissociative state as a result of hypocapnia, e.g., a renewed sense of self, may only be accessible while dissociated, i.e., a form of "chemical addiction." Emotions triggered while breathing normally may be avoided by overbreathing, i.e., changing states. Trauma is an excellent example of this where many clients may unwittingly learn to overbreathe. The reverse is also true, however, where troublesome emotions as a result of cerebral disinhibition, appear while in a dissociated state, but are absent while eucapnic, e.g., emotional communication during ***holotropic breathing*** (Grof & Grof, 2010).

EXAMPLE: A ten-year old boy from Japan who was having problems focusing on his work in school flew to the Unites States for a breathing assessment. While talking with the translator, the boy who had been continuously eucapnic (38 - 40 mmHg) suddenly began to overbreathe, bringing down his PCO_2 to a point of severe hypocapnia (20 - 22 mmHg). When asked about the change in his breathing, the boy remarked that "this is what I do in school." When asked why, he described it as a way of avoiding his teacher when spoken to, and as it turned out, his father as well. "Attention deficit" had been his diagnosis. Based on a breathing behavior analysis, a neurological explanation was abandoned and replaced with a both a programming explanation and solution.

Capnography technology

Breathing habit assessment requires capnography technology (Gravenstein et. al., 2011; Hennessey & Japp, 2007). Measurement of real-time changes in PCO_2, from breath to breath, makes possible observation of breathing behavior and its immediate impact on respiration and its associated acid-base physiology. There is no other kind of instrument that makes this possible, e.g., pulse oximetry. Capnographs are essential to identifying, editing, and learning breathing habits. Patients wear a nasal cannula during monitoring where real time changes in PCO_2 can be observed, PCO_2 rising during exhalation (metabolic CO_2) and falling to near zero during inhalation (room air CO_2). The real-time tracing of these changes, from one inhale to the next, constitutes the ***capnogram***. The capnogram provides valuable information regarding both respiratory chemistry and breathing mechanics. The peak value of PCO_2 at the "end" of the "tide" of air ($PetCO_2$), the exhale, is a measurement of alveolar PCO_2 ($PACO_2$) closely equivalent to arterial PCO_2 ($PaCO_2$). The shape of the capnogram provides valuable details regarding breathing mechanics, e.g., aborted exhalation, breathholding, effortful (pushed) exhalation, gasping, and struggling.

Personal data

Breathing habit assessment begins by collecting information. A combination questionnaire-checklist, ***Your Breathing Behaviors*** (Litchfield & Reamer, 2019), to be completed by clients (Appendix A), includes a behavioral history and a symptom checklist tethered to a list of possible habit triggers, i.e., situations (Appendix A). The contents of the form are discussed in detail with clients during the initial breathing interview while simultaneously monitoring and recording breathing physiology. Ongoing changes in breathing that compromise respiration are immediately pointed out and their triggers and effects discussed, e.g., a significant drop in PCO_2 is noted at the onset of a difficult conversation, or a gradual restoration of eucapnia appears while distracted from breathing. These kinds of self-discoveries are basic not just to assessment sessions, but also to ongoing learning sessions.

Questionnaire

The questionnaire portion of *Your Breathing Behaviors* provides valuable information. This information, discussed at the start of the initial interview, often plays a key role in how the ongoing session is structured and how it subsequently evolves, based on (1) possible measurement issues (e.g., effects of alveolar deadspace), (2) possible etiological factors (e.g., emotional abuse), (3) the presence of unique conditions often correlated with hypocapnia (e.g., fibromyalgia), (4) possible interactions with other conditions and challenges (e.g., panic attack), (5) implications for breathing testing (e.g., breathing-rate challenges), (6) presence of unexplained symptoms (often breathing-mediated), and (7) contraindications (e.g., intentional overbreathing protocols).

Checklist

The checklist portion of *Your Breathing Behaviors* is the initial interview centerpiece. The checklist is a list of 14 common symptoms and deficits associated with hypocapnia. Clients indicate the frequency of the relevant symptoms and specify the habit-trigger categories (from a list of 15) associated with them, e.g., dizziness, every day, while operating motor vehicles. In-depth guided exploration based on the checklist, while tying it together with behavioral history and live PCO_2 monitoring, sets the stage for insights usually unexpected by clients and not infrequently so by practitioners. Breathing habits may be causing some or all of the symptoms, or may simply be triggering symptoms brought on by other causes. If dizziness, for example, occurs in social situations while expressing personal feelings, but not elsewhere, the origin of symptom is likely behavioral hypocapnia, a programming rather than a mechanical issue. This hypothesis may be further corroborated by other checklist data (e.g., shortness of breath) in the same situation (e.g., social situations), behavioral history data (e.g., attention deficit), and actual dizziness triggered by the conversation itself during the interview. Interacting with clients in the context of sharing live physiology during an interview is ***transactional psychophysiology***.

Transactional psychophysiology

Transactional psychophysiology includes live physiology as a part of an evolving interview. As clients and practitioners interact around ongoing real-time capnography observations, clients identify personal breathing habits and their components including behaviors, triggers, motivations, and reinforcements. Clients also, along the way, reshape their belief systems and symptom interpretations based on their self-discoveries. The principal focus during the initial session is guided self-observation (to be described later), wherein the phenomenology of breathing, “what does it feel like,” takes center stage. Breathing behavior analysis is ***client-centered*** where clients are guided on a self-exploration journey during both assessment and learning sessions.

CASE EXAMPLE (a Type-3 breathing habit): A client discovered during the assessment interview that the sensation of phlegm in the throat served as a conditioned stimulus for air hunger that motivated coughing (also a behavior) and reaching for more air, while sitting in a dental chair. The consequence was hypocapnia. The symptom of primary importance was “throat closure.” The learned responses to the symptom included emotion (intense fear), cognition (catastrophizing), and action (exiting the chair). The solutions to this vicious circle habit included desensitization to the experience of phlegm (the trigger) and to “throat closure” (the symptom).

Breathing testing

Breathing testing protocols play a leading role in initial assessment. Customized testing protocols constitute breathing challenges based on behavioral history, checklist data, and capnography ($PetCO_2$) recordings. Some challenges may be in vivo (live) and others simulated or imagined (e.g., remembering a troubling experience). Here are examples of in vivo challenges while observing and recording PCO_2, either in the presence of a practitioner or independently: playing the piano, going to sleep, initiating a sport, writing an email, talking on the telephone, explaining a difficult concept, and taking a test. Some challenges are standardized, not customized. An example of a standardized test is the breathing-rate challenge test, where the range and stability of the chemical axis is assessed at different breathing rates; a person should be able to remain eucapnic despite significant changes in rate (5 - 25), as should be the case during daily life activities such as while talking, eating, working, resting, and moving.

Guided overbreathing

Guided overbreathing is a powerful assessment tool (Litchfield & Reamer, 2023)**.** Guiding clients into hypocapnia often leads to an impressive “aha” experience where clients discover for themselves how breathing habits are mediating symptoms and deficits in real life, including physical symptoms, emotions, and performance deficits.

Implementing overbreathing protocols requires training and experience to do so safely and productively. Clients are coached from a place of eucapnia into hypocapnia by taking larger and slower breaths. This strategy also helps clients to experientially address misguided beliefs about breathing mechanics and respiration, e.g., “deeper breathing is healthy.” Once PCO_2 concentrations are appropriately and relevantly reduced (e.g., 25 mmHg), based on interview content, clients are asked about physical symptoms, emotions, and thoughts that may be emerging. Clients are instructed to wait until recovery time before describing their experiences. Sometimes, specific challenges may also be introduced, e.g., cognitive challenges, such as “counting back by sevens from 400.” Simple challenges such as this during hypocapnia often serve to demonstrate the effects of behavioral hypocapnia on performance, e.g., a Ph.D. mathematician was unable to perform this very simple task - he reported that he couldn’t remember the preceding number.

After usually three to four minutes, coaching is discontinued and clients are asked to sit back and rest. Clients are interviewed about their experience during recovery, which should not require more than two to three minutes. Clients with dysfunctional breathing habits often do not recover and become trapped in vicious circle overbreathing where symptoms may even intensify, thus replicating the outcomes of dysfunctional habits in real life circumstances. When this true, self-intervention techniques are necessarily introduced for restoring eucapnia, e.g., taking smaller gentle breaths. The experience as a whole usually engenders an entirely new perspective of breathing that sets the stage for client-centered learning rather than practitioner-centered treatment planning.

CapnoLearning™

CapnoLearning™ is about learning habits that optimize respiration (Litchfield & Reamer, 2023)**.** It brings together physiology, psychology, and capnography technology to create powerful tools for identifying good and bad breathing habits, for learning to disengage habits that compromise physical and mental competence, and for learning new breathing habits that promote health and performance. CapnoLearning is the application of learning tools standardly used in behavior therapy worldwide for learning new behaviors and habits, the efficacy of which has been extensively documented across many decades of both research and clinical application (e.g., Miltenberger, 2023). These learning techniques when used specifically for addressing breathing behavior can be conveniently summarized by the anacronym, ***AIR***: "**A**" for **A**wareness-learning (self-observation), "**I**" for **I**ntervention (self-exploration), and "**R"** for **R**esolution (self-regulation). Each of these steps is ultimately required for effectively learning to disengage, edit, replace, and learn breathing habits. They are, however, not mutually exclusive steps, but rather they represent an evolving change in the focus of what is being learned, when and for what.

Self-observation (AIR: Awareness)

Habit modification, step 1, is self-observation, self-awareness-learning. This is difficult for many clients. When instructed to observe how "their body is breathing," they often immediately manipulate breathing, a behavior that often may in itself be the basis for learning a dysfunctional habit. Little progress can be achieved until they learn to self-observe, that is, until they learn how to distinguish body-learned behaviors from their own. The objective of self-observation is to discover unconscious habits including their specific behaviors, effects, triggers, emotions, motivations, reinforcements, histories, and accompanying beliefs and symptom interpretations. Consciously implemented techniques necessarily preclude observation of breathing habits at work.

EXAMPLE: One basic self-observation protocol frequently used in doing breathing behavior analysis is teaching clients to allow and observe exhalation, therein providing for discovery of embedded motivation and reinforcement that may be regulating dysfunctional mechanics, e.g., aborting and pushing breathing behaviors, often leading to hypocapnia, may be motivated by air hunger or anxiety about "getting enough air" and then reinforced by the occasional sense of relief from both. Unfortunately, however, this "only occasional" outcome serves to strengthen the habit rather than to weaken it, i.e., the ***partial reinforcement effect***. Although this protocol can take only minutes to accomplish, clients quickly learn how embedded psychology may be regulating breathing habits that mediate otherwise "unexplainable" symptoms, e.g., "I can't get my breath."

Self-exploration (AIR: Intervention)

Habit modification, step 2, is self-exploration, deliberate self-intervention. Learning about how breathing affects a client means intentionally changing breathing behavior and observing its outcomes, learning through playfulness and spontaneity. Self-exploration takes many forms, but basic to breathing behavior analysis is the ABA paradigm. The paradigm consists of observing the phenomenology (experience) of baseline breathing behavior A, followed by observation of changes in phenomenology (experience) triggered by the introduction of breathing behavior B, and then once again observing phenomenology (experience) triggered by the original baseline breathing behavior A. Behavior A vs. behavior B might be chest breathing vs. diaphragmatic breathing, fast breathing vs. slow breathing, breathing with transition time vs. without, or overbreathing vs. not. In the case of overbreathing, behavior A is usually eucapnic, or close to it (33-35 mmHg), and behavior B is hypocapnic. Learning through play helps clients to learn what feels good and what doesn't, to desensitize to alternative ways of breathing, and to discover new behaviors, motivations, and sources of reinforcement.

EXAMPLE: A client was asked to alternate between behavior A, chest-breathing (for two minutes) and behavior B, diaphragmatic-breathing (also for two minutes) for two cycles and during this time (total of eight minutes) to focus on which kind of breathing she preferred and why. Her initial answer was chest-breathing. When asked why, she explained that chest-breathing made her feel free and "in control." In contrast, diaphragmatic breathing triggered feelings of claustrophobia and air hunger. When asked to further elaborate, she explained that perception of "movement during chest breathing" freed her from a sense of "entrapment" in the diaphragm, the reinforcement for chest breathing. Through ABA self-exploration, within a few sessions she was able to find powerful positive outcomes, reinforcements, for diaphragmatic breathing. These reinforcements included sense of trust (i.e., awareness of reflex control by the diaphragm), removable of need for vigilance (i.e., having to remember to breathe), a sense of ease and effortlessness (i.e., reduced muscle activity), and removal of worry and anxiety about "how to breathe." ABA self-exploration had set the stage for learning to prefer "allowing" breathing to "controlling" it.

Self-regulation (AIR: Resolution)

Habit modification, step 3, is self-regulation, unlearning old habits and learning new ones. Self-intervention and self-regulation are not the same. One is about doing and the other about being. One is about controlling and the other about allowing. One is objective and the other intuitive. One is about symptoms and the other about causes. Self-interventions are breathing tools often useful for symptom management, but don't usually address breathing as behavior. Self-regulation is about ongoing breathing behavior and what autoregulates it, not about breathing techniques and their potentially useful applications. Learning new breathing habits is about changing "breathing personality," i.e., changing "who you are" from a breathing perspective. Habit modification includes unlearning breathing habits, editing breathing habits, and learning new breathing habits.

Crisis interventions

Learning self-interventions for managing hypocapnia is empowering. Arming clients with effective breathing techniques for managing behavioral hypocapnia is crucial to the ultimate success of any learning program. Being trapped in behavioral hypocapnia often lends itself to intense feelings of helplessness that can be terrifying, leading to the startling statistics reported earlier regarding ambulance runs as a result of overbreathing (Fried, 1999). Overcoming the fear of being trapped in hypocapnia, sometimes involving phobia of its symptoms (Ley, 1985), means being able to intentionally enter hypocapnia and return to a place of eucapnia through ABA negative practice to be discussed later.

There are many short-term breathing interventions helpful to restoring eucapnia (Litchfield & Reamer, 2023), e.g., taking smaller easy breaths, breathing as gently and effortlessly as possible, allowing rather than doing the breathing, opening the mouth slightly to reduce air hunger, minimizing the sound of breathing while listening through ear plugs, and thinking positive thoughts which may trigger alternative breathing habits that normalize respiratory chemistry. Although these self-intervention breathing techniques are important to learn, the objective of CapnoLearning is self-regulation breathing behavior, achieved through disengaging vicious circle breathing habits and learning new ones that optimize respiration.

Learning plans

Breathing habit modification begins with the formulation of a learning plan. The plan is always customized to client habit details discovered during breathing behavior assessment, including recommended reprogramming (learning) techniques along with carefully planned homework assignments to be conducted in the field. Some of the principal learning techniques used in CapnoLearning are described below.

Desensitization

Extinction, i.e., unlearning, of classically conditioned responses, or their inhibition (***counterconditioning***), is fundamental to most learning plans, e.g., air hunger, fear, anxiety, claustrophobia, nausea, muscle contraction (smooth and skeletal), even symptoms such as dizziness (Bresseleers, 2010), and other physiological changes of all kinds. These learned responses play a key role as motivation for learning breathing behaviors, as a basis for reinforcing breathing behaviors (e.g., air hunger reduction), and as convincing evidence for misguided beliefs about breathing and symptom interpretations.

Desensitization may be relevant to (a) breathing experience as a whole, where even noticing breathing is fear-provoking, (b) specific kinds of breathing experiences, e.g., fast breathing triggers anxiety (type-2 habits), (c) hypocapnia symptoms, e.g., throat closure triggers panic (type-3 habits), (d) external events ranging from physical to social, e.g., sitting in a dental chair triggers claustrophobia (Type-1 habits), (e) internal events, e.g., phlegm triggers nausea, (f) metaphor (semantic stimulus generalization) e.g., social confrontation triggers bronchial constriction, and (g) cognition, e.g., memories trigger gasping.

Exposure to triggers (conditioned stimuli), without negative consequences, leads to gradual extinction of the responses associated with them. Although seemingly simple, success often requires careful planning. Poor planning can unwittingly lead to exacerbation and perpetuation of vicious circle habits. Desensitization procedures differ from the perspective of how clients are exposed to the triggers (conditioned stimuli) in question, including (a) ***direct exposure***, e.g., extinction of fear triggered by "the experience fast breathing" through systematic exposure to variable breathing rates (ABA paradigm, 8 vs. 16), (b) ***gradual exposure*** (***systematic desensitization***), e.g., extinction of hypocapnia phobia through deliberate, systematic, and successive intensification of symptoms, and (c) ***incompatibility exposure***, i.e., ***counterconditioning***, e.g., extinction of air hunger during exhalation-inhalation transition times through discovery of the inhalation reflex, wherein sense of confidence or relief blocks classically conditioned air hunger.

Perceptual learning

Learning awareness often by itself leads to finding new motivations, behaviors, and reinforcements. Self-discovery of the inhalation reflex, for example, through self-observation during the exhalation-inhalation transition time, often leads quickly to self-regulation breathing, that is, to "allowing the breathing" and finding its powerful inherent self-reinforcing properties, the benefits of trust. By virtue of stimulus generalization, ***allowing and being*** the breathing ***rather than manipulating and doing*** the breathing may thus become the unconsciously preferred breathing option at times of stress and challenge, triggers that may have previously led immediately to overbreathing and hypocapnia.

Negative practice

Clients become experts at performing the "wrong behavior," engaging and disengaging the habit, and turning the habit ON and OFF at command in the presence of its triggers (an ABA protocol). It means deliberate and planned practice of dysfunctional habits. It teaches taking ownership of breathing habits that compromise health and performance. In so doing, clients may develop an awareness of how they may have unwittingly trapped themselves in vicious circle breathing behavior and how to allow for reflexive respiratory regulation. The feeling of being at the mercy of a habit, a victim, significantly diminishes or disappears altogether, offering the prospect of addressing its cause (and its possible history) rather than just the symptoms it mediates. Clients therein lose their fear of the habit, and should it unexpectedly arise (***spontaneous recovery***) can detect it early on and usually consciously disengage it. Negative practice provides for discovery of (a) breathing behaviors that compromise or optimize respiration, (b) physiological and psychological changes associated with breathing, (c) habit triggers and their associated motivations, (d) operating and potentially new reinforcements, (e) faulty belief systems and misguided symptom interpretations, and (f) breathing behaviors, habits, and patterns that are aligned with respiratory and acid-base requirements.

Biofeedback

Continuous real-time feedback of live breathing physiology, including PCO_2 and related breathing mechanics (capnogram parameters), teaches clients about the effects of breathing behaviors on respiration and acid-base physiology and the symptoms and deficits that they may mediate. PCO_2 biofeedback makes breathing self-exploration possible based on both science and experience, wherein breathing habits that optimize respiration and its associated physiology can be identified and learned. Clients develop a nuanced somatic awareness of both breathing mechanics (the behaviors) that serve respiratory chemistry and the incipient physiological changes associated with respiratory compromise, subtle experiences that become triggers for new breathing habits that maintain alignment of mechanics with chemistry requirements, i.e., self-regulation breathing. Clients phenomenologically learn to appreciate subtle physical, psychological, and behavioral changes mediated by breathing habits. PCO_2 biofeedback is a multifaceted protocol which necessarily includes awareness learning, desensitization, and negative practice.

Clients learn to bring about specific concentrations of $PetCO_2$, down and then up, at command by interacting with the live presentation of raw PCO_2. In so doing they learn to (1) become aware of emotions, thoughts, and symptoms that emerge at each level $PetCO_2$, (2) navigate breathing behavior relationship dynamics that bring them into hypocapnia, and (3) allow brainstem reflexes to restore eucapnia (35 - 45 mmHg). They develop a discriminating sense, a finely tuned awareness, of even the smallest of nuances, arising from differing levels of hypocapnia ($PetCO_2$). Clients become keenly aware of not only changes in physicality, but also changes in feelings, thoughts, and consciousness. The behavioral objectives of PCO_2 biofeedback learning include (from Litchfield & Reamer, 2023):

● Learn "how to" overbreathe. Take charge of the habit.
● Learn to easily and rapidly restore eucapnia, i.e., 2-3 minutes.
● Learn to recognize the symptoms and deficits associated with your hypocapnia.
● Extinguish learned air hunger motivation.
● Extinguish fear of entering hypocapnia and its associated effects, i.e., disengage Type 3 breathing habits.
● Extinguish fear of specific breathing mechanics, e.g., faster breathing, i.e., disengage Type-2 breathing habits.
● Maintain eucapnia (stable chemical axis) while relaxed or aroused.
● Maintain eucapnia while within a wide range of breathing mechanics, e.g., different rates.
● Maintain eucapnia while in the presence of old habit triggers.
● Establish hypocapnic symptoms as triggers for new habits that support self-regulation.
● Learn to implement effective self-intervention techniques during times of spontaneous recovery (crises).

Key points to remember about identifying, disengaging, editing, and learning breathing habits that compromise or optimize respiration and its associated acid-base physiology are as follows (from Litchfield & Reamer, 2023):

● Become a self-observer, learn the difference between observing and participating.
● Develop awareness of symptoms mediated by breathing habits, i.e., Type-1 habits.
● Develop awareness of breathing mechanics that trigger emotions, thoughts, and actions, i.e., Type-2 habits.
● Develop awareness of symptoms that trigger emotions, thoughts, and actions, i.e., Type-3 habits.
● Address misguided beliefs and interpretations that keep habits in place.
● Learn to use self-interventions for unexpected spontaneous recovery of habits and crisis intervention.
● Learn to explore, to be playful with your breathing to confirm habit outcomes, good and bad.
● Disengage motivation and emotion triggered by breathing with desensitization procedures.
● Disengage emotion triggered by breathing-mediated symptoms with desensitization procedures.
● Learn new motivations, emotions, and thoughts that support linking mechanics with chemistry.
● Disengage reinforced breathing behaviors by identifying and withdrawing reinforcement.
● Use negative practice as a way of editing, managing, disengaging, and learning breathing habits.
● Establish preferences for new breathing behaviors through self-exploration.
● Learn new breathing behaviors in the presence of old habit triggers.
● Identify, create, and use reinforcements for establishing new breathing behaviors and habits.
● Create triggers for new habits that replace and/or compete with older habits.
● Test yourself. Confirm the absence of old habits and the presence of new breathing habits.
● Make hypocapnic symptoms and/or deficits triggers for new breathing habits that optimize respiration.
● Generalize habits by metaphor that optimize respiration.

The mechanical model

The ***mechanical model*** of breathing focuses on ***diagnosis*** and ***treatment*** of ***breathing disorders***, e.g., dyspnea (shortness of breath), based on identifying physical limitations that may be compromising respiration, including anatomical features such as the presence of a narrow airway that may be restricting airflow, thus leading to dyspnea. Based on a mechanical analysis, the explanation for dyspnea might be hypoxia and the recommended solution structural management (e.g., an appliance), a drug (e.g., a muscle relaxant), or even surgery. Metaphorically speaking, "the computer doctor" assesses the issue as a case of "inadequate RAM" and recommends "adding more RAM" to the computer as a potential "treatment."

The airway may be narrow and there may be hypoxia, but the reason for the hypoxia may be unrelated to the airway itself. Breathing mechanics that serve (external) respiration are regulated by brainstem reflex mechanisms, as previously described, and are easily compromised by breathing habits leading to hypocapnia and its associated cerebral hypoxia (vasoconstriction) and red cell alkalemia (Bohr effect). The "narrow airway" may, however, be an important part of the puzzle in that it may have set the stage for the original programming, i.e., the learning of the habit, and should surely not be overlooked. Overlooking programming (learning) history, however, would likely restrict problem solving to only mechanical solutions.

The behavioral model

The ***behavioral model*** of breathing focuses on ***behavior analysis*** and ***learning solutions*** (reprogramming) for identifying and modifying breathing behaviors, habits, and patterns, i.e., vicious circle breathing habits that mediate respiratory compromise and hypocapnia symptoms, e.g., dyspnea. Based on a behavioral analysis, the explanation for dyspnea might be (a) "aborting the exhale" behavior (i.e., not allowing the exhalation to complete) is (b) triggered by "worry about getting enough air," where (c) "aborting the exhale" (a behavior) leads to (d) feelings of "not being able to take a deep breath," i.e., claustrophobia - air hunger, that (e) ***motivates*** "aborting the exhale" (the original behavior) and deeper breathing (also a behavior), that are both (f) ***reinforced*** by occasional air hunger reduction (which strengthens the habit) as a result of (g) ***external inhibition*** (effects of distraction), resulting in (g) hypocapnia which (h) almost immediately precipitates cerebral and other kinds of tissue hypoxia (even ischemia). The solution from this perspective is disengagement of the breathing habit, its inhibition, and/or its replacement with a habit that is aligned with respiratory chemistry requirements.

Practical consequences

When breathing is not understood as behavior, i.e., when its psychophysiology is overlooked, breathing and respiration become synonymous. The role of breathing habits in dysfunctional breathing is then necessarily and entirely overlooked, of course - breathing habits are behavioral, respiration is reflexive. Misguided "diagnoses" and "treatment" recommendations based thereon may be the outcome as described in detail below.

1. Breathing-mediated symptoms and deficits are mistakenly attributed to unrelated causes.

When breathing is not understood as behavior, the physiological changes and their associated symptoms triggered or mediated by dysfunctional breathing habits may be mistakenly attributed to unrelated causes by both clients and practitioners.

(a) Breathing habits (e.g., deeper breathing when feeling claustrophobic) may ***directly cause*** physiological changes (e.g., reduced cerebral blood flow), symptoms (e.g., nausea), and deficits (e.g., brain fog) that may, for example, be mistakenly attributed to anxiety or a physical condition, rather than to the ***breathing behavior learned in response to*** anxiety or a physical condition. The ultimate solution, insofar as the habit is concerned, is not anxiety reduction. Anxiety reduction by itself, although indeed helpful and important, does not address the habit and its unique configuration. The next time the client is anxious, the habit will reappear. The solution is to address the cause, i.e., the habit, and not simply the "whenever possible" removal of its trigger, the anxiety. The final solution necessarily includes the presence of anxiety without hypocapnia.

(b) Breathing habits may ***lower or raise thresholds*** for the appearance of symptoms and deficits triggered by independent physical (e.g., epilepsy) and/or mental (e.g., panic) etiologies, e.g., habit-mediated cerebral hypoxia and hypoglycemia increase the likelihood of bringing on symptoms associated with neurological conditions.

(c) Breathing habits may ***exacerbate and/or prolong*** symptoms brought on by other causes, e.g., asthma symptoms (airway resistance) trigger "taking control of breathing," reinforced by "feelings of being in control," that lead to hypocapnia, thus exacerbating the intensity of the symptoms, prolonging the presence of the habit triggers themselves (the symptoms), and introducing new symptoms also then mistakenly attributed to asthma, e.g., brain fog, rather than to the outcome of the habit, behavioral hypocapnia.

(d) Breathing habits may trigger ***unexplained symptoms***, mediated by behavioral hypocapnia, that cannot be readily explained by convenient reference to organic etiologies. Unexplained symptoms are usually washed away with "it's all in your mind" or, given they cannot be explained otherwise, are attributed to popular health-compromising theories, e.g., dietary deficits and effects of social media. How often is physiological programming, e.g., breathing habits, considered a possible factor? Consider the mind-bending ambulance-run statistics in the United States otherwise unaccountable (Fried, 1999). Medically unexplained symptoms continue to be a significant challenge in primary care (Chew-Graham et. al., 2017).

(e) The effects of symptoms mediated by behavioral hypocapnia are often ***confused with symptoms*** arising from unrelated physical and/or psychological conditions. EXAMPLE: Campbell (recorded interview, 2010) reported on a patient who attributed his vomiting to the drug he was taking for pain management (an injury), only to find out during breathing behavior assessment that vomiting was indeed not a drug side effect but was rather the consequence of behavioral hypocapnia mediated by a breathing habit learned while coping with pain.

2. Prescriptive mechanical solutions predominate and reinforce victim-thinking.

When breathing is not understood as behavior, symptoms and deficits mediated by breathing habits are almost inevitably blamed on external factors to be avoided or controlled, wherein (a) avoiding these factors may then serve to reinforce victim-thinking as well as (b) encouraging practitioners to implement "interventions," unrelated to the actual causes, for symptom control.

EXAMPLE: A company employee suffers headaches during times of high stress while at work. Logical thinking, from a mechanical perspective, might be that "stress causes headaches, at least for many people, and that in those cases, relaxation self-interventions might be recommended. Headache is blamed on physical and social stressors that require "stress management, e.g., lifestyle changes and relaxation techniques. The behavioral perspective, however, offers an alternative kind of analysis. That is, perhaps the headache is the result of a learned breathing response to the stress, i.e., behavioral hypocapnia leads to cerebral hypoxia and hypoglycemia along with compromised hemoglobin chemistry (Bohr effect). The solution from a physiological learning perspective would be disengagement of the habit, therein making it possible to be stressed during challenging times without developing a headache. Avoiding stress and managing its symptoms with self-interventions, from a headache perspective, are no longer necessary.

3. Breathing habits become physical disorders that require treatment, e.g., medication.

When breathing is not understood as behavior, dysfunctional breathing may be misinterpreted as a physiological "disorder," a clinical problem that requires "treatment," e.g., medication for gasping. From a mechanical perspective gasping may, for example, be considered as a physiological symptom of asthma. From a behavioral perspective gasping may be a learned behavior, a classically conditioned reflex learned during asthma episodes and/or as a reinforced behavior connected with "learned helplessness" (secondary gain). That is, gasping can be both classically conditioned, i.e., a conditioned reflex, or instrumentally conditioned, i.e., a reinforced response.

EXAMPLE: A nurse practitioner was medicated for gasping, presumably brought on by her asthma. When she was asked to insert earplugs and listen to her breathing, the gasping stopped in less than a minute. When earplugs were removed, gasping began once again. Her gasping during breathing behavior analysis could not be accounted for by simple reference to asthma. The audibility of her breathing, i.e., the awareness of her breathing, effectively inhibited classically conditioned gasping. The context of the habit had been changed. Stimulus control ceased. Trigger (stimulus) generalization ended. The recommended solutions included exploration of habit history, identification of specific triggers, desensitization to relevant triggers, negative practice (taking ownership of the symptoms), and cognitive learning (symptom interpretations).

4. Breathing folklore, rituals, and misguided techniques arise easily and quickly.

When breathing is not understood as behavior, breathing becomes exclusively physiology to manipulate in the service of physical (e.g., relaxation), psychological (e.g., trauma memory exploration), and spiritual (meditation) objectives, that is, breathing self-interventions of all kinds. Most of these techniques are perhaps best described as helpful rituals, but surely do not directly and/or informatively address respiration and its compromise or optimization, e.g., dancing, rocking (children), and slow breathing when properly introduced have rhythmic movement in common that may be effective ways of relaxing and altering awareness. Breathing, as the behavior at the center of a ritual, however, is different from other rituals in one important respect: altering it can have immediate and profound effects on physiology that may unwittingly set the stage for its unique and special reputation, current and historical.

Mechanical models in most cases offer methods for DOING rather than ALLOWING breathing, wherein the cause of a breathing-related problem may become its own self-defeating (vicious circle) solution, practices that may actually teach and/or perpetuate dysfunctional habits. Learning a dysfunctional breathing habit, from a respiratory perspective, is ultimately about deregulation of brainstem reflexes (often leading to hypocapnia) based on having learned to "take control" of breathing in the name of health or improving performance. Some breathing self-interventions, however, do indeed specifically address the subject of respiration, e.g., the Buteyko technique, but do not address breathing as behavior.

EXAMPLE: Buteyko methodology is intended to help people with hypocapnia restore eucapnia, normal PCO_2 concentrations (Bruton, 2005). Here is a behavioral critique of the Buteyko methodology. The same analysis applies to other such interventions as well.

(a) Is there hypocapnia? Many Buteyko practitioners rely on BOLT scores to determine whether or not there is hypocapnia. The test is a measurement of the length of time a person reports being able to remain comfortable (without air hunger) during the exhalation-inhalation interval, often referred to as a measurement of CO_2 tolerance, i.e., the longer the comfort zone, the higher the tolerance. The assumption is that "CO2 tolerance," although not a direct measurement of PCO_2, is correlated with hypocapnia. There are, however, no formal correlational studies reported in the literature that support this hypothesized correlation. The one relevant study (Kowalski et. al. 2024) reported, failed to support the practical relevance of BOLT scores during exercise performance. Nevertheless, the correlation would logically be expected; people who worry about their breathing are both more likely to overbreathe and less likely to tolerate waiting to take a breath. The inhalation respiratory reflex that occurs within a second or less after exhalation is normally accompanied by air hunger as it should be. It represents conscious awareness of the embedded motivation for the next breath. If there is indeed a correlation, its likely explanation is psychophysiological as described above. Making practical decisions about whether or not there is a CO_2-related dysfunctional breathing issue for any specific individual, based on a BOLT score, is misguided.

(b) Is the hypocapnia acute? Most people are not hypocapnic "in general." Most cases of hypocapnia are acute, not chronic, that is, people who suffer the effects of hypocapnia are comfortable at normal levels of PCO_2 concentration (eucapnia). Their problem is the onset of hypocapnia symptoms at lower PCO_2 concentrations, an issue accounting for 60% of the ambulance runs in the larger USA cities (Fried, 1999), the tip an immense iceberg of people suffering with acute hypocapnia. Breathing behavior changes very specifically, as a function of stimulus control, where specific learning histories dictate if, when, and where a habit is triggered. Identifying breathing habits that disturb PCO_2 regulation, that is, the H-H equation, requires capnography technology for real-time monitoring of PCO_2 concentrations during a breathing-centered interview where behavioral variables can be sorted.

Buteyko techniques are designed to help people learn to "tolerate" ("prefer," better said) higher or normal levels of PCO_2. People suffering with acute hypocapnia do not need to develop "tolerance" to higher concentrations of PCO_2. They are already comfortable at normal concentrations and prefer to be eucapnic. Their dysfunctional habits lead them into hypocapnia where they become victims of their own learned vicious circle breathing behavior as described earlier in the chapter. Learned responses to hypocapnia symptoms themselves (Type-3 habits), e.g., fear of losing control, further motivate the dysfunctional behavior and exacerbate the symptoms already present. *People don't call for an ambulance because they "can't tolerate" normal levels of PCO_2 concentration.* In fact, ***desensitizing*** clients to the experience of hypocapnia symptoms by coaching them into and back out of hypocapnia, negative practice, is an important part of behavioral solutions to acute hypocapnia. Buteyko techniques are not at all useful for people with habits that bring about acute hypocapnia, nor would they be expected to.

(c) Is the hypocapnia chronic? In the case of chronic hypocapnia, where people overbreathe continuously, ***sensory adaptation*** to lower levels of PCO_2 takes place. There is an extensive neurobehavioral literature describing sensory adaptation and related habituation (Rankin et. al., 2009). When sensory adaptation to lower concentrations has taken place, restoring higher concentrations (eucapnia) also requires sensory adaptation, that is, from a behavioral perspective classical forms of ***desensitization training***. Buteyko describes sensory adaptation as a "setpoint" readjustment, i.e., learning to "tolerate higher concentrations of PCO_2. "Toleration," however, is a poor choice of words. Learning "to like" or "to prefer" eucapnia makes more sense from a behavioral perspective as preferences, not requirements to tolerate, motivate behaviors.

(d) How can chronic hypocapnia be effectively addressed? An important question in respect to chronic hypocapnia is its etiology. Buteyko analysis points to external factors, e.g., stress, which may cause hypocapnia, a mechanical-model hypothesis. But if so, how so? What is the explanation, what are the mechanisms? Respiration is robust, it can be optimal in the most challenging situations, including stress.

Dysfunctional breathing habits, like all habits, are regulated by specific triggers based on a learning history, e.g., for some people stress brings on a sense of claustrophobia and its associated air hunger that may motivate "taking deeper breaths" reinforced by a feeling of being in control. The result may be a vicious circle habit that perpetuates the hypocapnia until a different trigger emerges, e.g., leaving the scene. Thus, it is not the stress itself that causes the hypocapnia but rather it is the learned breathing response to the stress (the habit trigger) that mediates the hypocapnia, as described earlier in the chapter. The solution is learning to disengage the habit and/or replace it with a new one consistent with aligning breathing mechanics with respiratory chemistry requirements. Avoiding stress is avoiding the habit and does not address the cause. If the cause is not addressed, the habit will persist as habits so powerfully do.

Teaching increased tolerance to PCO_2 concentrations without addressing the causes that perpetuate the habit, is not likely to be effective. Most Buteyko practitioners, however, do not even measure PCO_2 to know whether or not the tolerance training has been effective. An improved BOLT score may mean that you can tolerate higher PCO_2 concentrations, if in fact that is what it measures, but it does NOT mean that the triggers for the habit have been addressed. That is, although a person can now perhaps tolerate higher PCO_2 concentrations, the habit may still persist. Simply learning to tolerate higher concentrations does not necessarily address the etiology of the habit and the factors that sustain it.

(e) When is Buteyko effective for managing chronic hypocapnia? Consider the following two anecdotal cases, where two Buteyko practitioners were chronically hypocapnic. They were highly experienced Buteyko practitioners with many years of experience. Both of them had implemented PCO_2 tolerance training in regard to their own breathing and were certain, based on their own Buteyko self-assessment, that PCO_2 concentrations were normal. How could they be so misguided? Besides not making PCO_2 measurements to confirm their assumptions, both Buteyko assessment and training techniques were not relevant to their PCO_2-related breathing issues. Upon conducting a psychophysiological assessment, a breathing behavior analysis in each case, the habits were quickly identified: (1) in the first case, the subject learned overbreathing behavior that mediated dissociation as a means of escape from traumatic memories, and (2) in the second case, the kinesthetic experience of small breaths in the diaphragm brought on feelings of claustrophobia that motivated taking larger breaths, on a chronic basis, which provided a sense of relief and control. PCO_2 tolerance training was an irrelevant strategy for overcoming these habits, hence their failure. Both practitioners were indeed surprised to learn what they did about the psychophysiology of their own breathing.

Buteyko techniques can surely, however, be immensely helpful to some people suffering with chronic hypocapnia. This depends, however, on the origin of the overbreathing problem and its specific psychophysiological dynamics (e.g., motivation). Systematic extension of the time between exhale and inhale (the hallmark of Buteyko work, i.e., the "controlled pause"), from a behavioral perspective, can support normalization of PCO_2 concentrations (eucapnia) by providing for: (1) extinction (desensitization) of classically conditioned fear and air hunger that motivates taking larger breaths, breathing faster, mouth breathing, and aborted exhalation; (2) extinction of self-defeating cognition about breathing (worry and self-talk); (3) awareness (perceptual) learning through self-discovery of the brainstem respiratory inhalation reflex that teaches trust (confidence) in body intelligence, (4) reinforcement of "allowing" (the reflexes) rather than "doing" the breathing, i.e., vigilance and effort are no longer required; and (5) sensory adaptation to higher PCO_2 concentrations which constitutes withdrawal of reinforcement, i.e., the elimination of "air hunger reduction" as a reinforcement that sustains vicious circle breathing behavior. All of these considerations could, in some cases, have a major positive impact on the self-defeating psychophysiology of chronic hypocapnia.

5. The potentially crucial role of psychological variables is entirely overlooked.

When breathing is not understood as behavior, prescriptive breathing techniques predominate and become the exclusive focus of practitioners everywhere. Breathing becomes a universal "tool" for assisting people in myriad ways, ranging from managing anxiety to improving athletic performance. Lost in the shuffle is the psychophysiology of breathing, the personal physiological programming history that plays a crucial role in the regulation of everyday breathing and the alignment of its mechanics with respiratory chemistry requirements. Overlooking programming history blocks identifying breathing habits and addressing the relevance of learning, motivation, attention, reinforcement, and other behavioral variables that govern these habits. Here are two examples of how a mechanical perspective often fails to adequately explain and address hypocapnia:

EXAMPLE: Mouth breathing causes hypocapnia (overbreathing). Nose breathing restores eucapnia.

One common misguided analysis of mouth breathing based on a mechanical model is the relationship between mouth breathing and ***overbreathing*** (breathing that leads to hypocapnia). The mechanical model proposes that one behavior (mouth breathing) necessarily leads to another (overbreathing), the assumption being that there is a physical basis for their connection. There is, however, no evidence for this, besides the fact that there is a likely correlation between the two behaviors. A correlation, of course, is not a cause-and-effect relationship.

Respiration is fundamentally regulated by chemical factors: arterial PO_2 concentration, arterial and cerebrospinal fluid PCO_2 concentration, and arterial and cerebrospinal fluid pH. Thus, although mouth or nose is irrelevant from a physical respiratory regulatory perspective, it is indeed relevant from a psychophysiological perspective. This relevance is illustrated by explaining the following: (a) many clients who overbreathe while nasal breathing (i.e., are hypocapnic), ***almost immediately stop doing so*** when they are instructed to slightly open their mouths (i.e., are eucapnic), whereas (b) others, who overbreathe while mouth breathing take ***a long period of time*** to learn to disengage overbreathing by practicing nose breathing. The mechanical model cannot explain these disparate findings. The behavioral model, however, can do so easily.

In the first case, where clients who overbreathe while nose breathing halt immediately doing so when they open their mouths, the behavioral model predicts this outcome based on the following: (a) nasal resistance creates claustrophobia and air hunger which motivates “reaching for more air;” (b) mouth breathing eliminates this resistance and is thus immediately reinforced by air hunger reduction; (c) “reaching for more air” is no longer reinforced by air hunger reduction; (d) worrying about “getting enough air” ceases; and (e) “allowing’ for the inhalation respiratory reflex is immediately and highly reinforced by multiple reinforcements, e.g., reduced effort, air hunger reduction, no need for vigilance (worry about getting enough air), and a personal sense of trust in one’s own physiology.

In the second case, where clients who overbreathe while mouth breathing learn with practice to prefer breathing through the nose, the behavior model predicts this outcome based on the following: (a) worry about “getting enough air” motivates “taking over the breathing” by opening the mouth, taking larger breaths, breathing faster, and chest breathing - all behaviors likely to lead to overbreathing, though not necessarily, and (b) the presence of resistance while practicing breathing through the nose may set the stage, in some cases, for learning “to allow” effortless, small, and gentle breaths that provide for self-discovery of how “doing” the breathing with larger breaths is a self-perpetuating vicious circle habit that promotes self-fulfilling prophecy thinking (e.g., I won’t get enough air).

6. Faulty conclusions regarding breathing mechanics and their effects on physiology are likely.

When breathing is not understood as behavior, misguided understandings, misinterpretations, and incomplete explanations of the outcomes of breathing techniques are likely. Here is an example:

EXAMPLE: “Slow breathing lowers blood pressure,” wherein from a mechanical perspective, “slowness” is almost necessarily given physiological credit for its success. In fact, Respirate, a well-known commercially available breathing training device, a breath pacer, has been shown that statistically speaking the practice of slow breathing does indeed reduce blood pressure. The kind of logic offered to account for its success is typically physical, mechanical, based on an autonomic nervous system model, i.e., parasympathetic training reduces blood pressure.

The behavioral model, however, offers another more comprehensive perspective, a psychophysiological one, that is, what is the psychophysiology of “slowness?” As previously described, the experience of [a breathing behavior] can itself be a trigger for another habit, a Type-2 breathing habit, where “slow breathing” may trigger learned emotions, cognitions, and actions (other behaviors). It is not uncommon, for example, that small and gentle but rapid breaths trigger relaxing thoughts and relaxed muscles, or that slow larger breaths bring on air hunger and worry about getting enough air. Behavioral rituals of all kinds that are conducted slowly and rhythmically may, however, constitute a kind of parasympathetic management including breathing as a behavior, but what does this have to do with respiration? Was it the autonomic change that lowered the blood pressure or were both the autonomic change and the lower blood pressure the result of a third underlying variable, i.e., the disengagement of a breathing habit mediating hypocapnia that accounted for both observations (changes); hypocapnia causes immediate vascular constriction and triggers hypertension in susceptible individuals.

The benefit of “slow breathing” for amelioration of hypertension is statistical and for many people it may have no effect whatever. Slow breathing for many people means taking larger breaths and along with it, the risk of overbreathing and hypocapnia. The behavioral model predicts success of “slow breathing” based on breathing learning history in combination with physiological propensities and related lifestyle compromises. Breathing habit histories and the components that define them, vary greatly from one person to the next, where in one case “slowness” addresses the relevant psychophysiology, but not in others, e.g., overbreathing to dissociate and avoid feelings and thoughts.

Slow breathing may set the stage for learning and unlearning (extinction) breathing habits. It makes possible (a) extinction (unlearning) of classically conditioned fear and air hunger elicited at the end of the exhale and during transition time between exhale and inhale that motivated the unconscious hijacking or commandeering of the respiratory brainstem reflex mechanisms that regulate respiration; (b) extinction (unlearning) of highly reinforced avoidance behavior (instrumental conditioning), e.g., taking a breath before the end of the exhale, previously reinforced with anxiety reduction, air hunger reduction, and an improved sense of personal control; (c) disengagement of vicious circle breathing behavior self-perpetuated by a claustrophobic-driven sense of "having run out of breath;" (d) learning to "allow the breathing," now reinforced with a sense of ease, anxiety reduction, air hunger reduction, and a reduced sense of urgency; and (e) learning awareness of the "inhalation' reflex during the exhale-inhale transition time leading to a sense of biological trust, a mega-reinforcement for allowing breathing and respiration to realign themselves, that is, giving up the perceived need for "doing the breathing." Slow breathing protocols may incidentally address these factors.

Credit for success is almost invariably given to the manipulation of physiology, i.e., slow breathing for parasympathetic management, rather than to psychophysiological history and realignment of breathing mechanics with respiratory chemistry. Breathing behavior analysis provides for a detailed sorting out the relevant behavioral variables.

7. Breathing self-intervention becomes synonymous with breathing self-regulation.

When breathing is not understood as behavior, "self-regulation" translates into "self-intervention," where emphasis is on self-managing rather than self-regulating. Most healthcare practitioners think self-intervention.

As discussed earlier, self-intervention is about *manipulating breathing physiology* for symptom management, i.e., prescriptive interventions that may successfully serve to avoid or block unidentified breathing habits but not resolve their etiologies. Learning to be "your own doctor" is an "outside-in" intellectual approach to improving health and performance, where emphasis is on "treatment" and "the doctor." An example, as described previously, is learning diaphragmatic breathing and relaxation techniques as self-administered "treatments" for headaches. The probability of headaches as a symptom is addressed but not its cause, that is, dysfunctional breathing habits learned in response to the stress are neither identified nor addressed. The techniques remain as helpful self- administered "prescriptions," but usually do not address the habits, even incidentally.

Self-regulation is about learning, i.e., programming new physiological configurations. It is about identifying, modifying, and replacing embedded breathing habits. Self-regulation is about embedding new habits that automatically align breathing mechanics with respiratory chemistry requirements, most of the time, i.e., an "inside-out" intuitive learning approach to maintaining eucapnia and a stable chemical axis. Unlike the mechanical approach, as described above, clients identify breathing habits, disengage the challenging ones, and learn new ones based on awareness learning, partnership with the body, and allowing basic respiratory reflex mechanisms to take charge, i.e., self-regulation. The new breathing habits become as resilient ("intractable") as the older dysfunctional ones, habits that may have persisted for many years, even decades. Self-regulation for the most part precludes the necessity for prescriptive interventions, although self-interventions also serve as important backups.

8. Overlooking breathing history can easily lead to faulty health assessment interpretations.

When breathing is not understood as behavior, physiological measurement made without reference to possible physiological programming (learning) history may result in false conclusions regarding physical and psychological health.

If medical and psychological assessment protocols are performed while patients are hypocapnic, the results in some cases may likely be misinterpreted. Examples include (a) **brain scan assessments** (e.g., effects of cerebral hypoxia, electrolyte shifts, and neuronal acidosis on concussion and attention deficit diagnoses), (b) **electrolyte deficiency testing** (e.g., bicarbonate concentration determination based on $PaCO_2$ measurement during acute hypocapnia), (c) **vestibular testing** (effects of dizziness, disorientation, loss of balance and coordination, muscle weakness during testing), (d) **hypertension assessment** (effects of increased vascular resistance), (e) **vision testing** (reduced ocular blood flow), and (f) **psychological assessment** where myriad hypocapnia symptoms are mistakenly attributed to other causes, e.g., low self-esteem (Fensterheim, 1994). See previous quotation.

Scientific theory

Theory in science is about prediction and practicality. Some scientific theories are better than others, i.e., they are more practical. The behavioral model of breathing, which offers a psychophysiological perspective, is more practical than the mechanical model of breathing which speaks only to anatomy and its associated reflexes. The behavioral model is more inclusive, makes better predictions, and accommodates more data. It surely does not, however, leave out the anatomy and reflexes that dictate the limits of physiological programming.

Fensterheim (1994) suggested that breathing behavior assessment "…should *be a routine part of every psychological evaluation, regardless of the specific presenting complaints.*" The analysis presented here points to the same conclusion, that is, some form of basic breathing behavior analysis should be included as a service in healthcare at large. Breathing behavior assessment can be quickly accomplished and it is inexpensive.

Drugs, surgery, and appliances address anatomy and reflexes, but do not generally address programming issues, that is, the complexities of breathing as behavior. CapnoLearning, based on the integration of respiratory physiology with behavior analysis, offers powerful behavioral solutions to so many struggling with behaviorally compromised respiration and its associated acid-base physiology. Learning about physiology as a programmable system, and the basic principles by which it operates, is significantly relevant to the work of practitioners everywhere interested in breathing and respiration. The authors of this chapter propose that breathing behavior analysis be the foundation of a new practical breathing science, a science that focuses on physiology as programmable behavior, a missing link in healthcare.

We all have breathing habits, some of which may compromise respiration where breathing mechanics become misaligned with respiratory chemistry. Their effects on physiology can be profound, resulting in debilitating physical symptoms, psychological changes, and performance deficits. Unfortunately, habits that compromise respiration are rarely identified, their effects mistakenly attributed to other causes, and their resolutions prescriptive in nature where focus is on symptoms rather than on causes, e.g., relaxation techniques. Understanding breathing as behavior governed by both physiological and behavioral principles puts these shortcomings into perspective and offers solutions based on breathing behavior analysis.
(Litchfield & Reamer, 2022)

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APPENDIX A

YOUR BREATHING BEHAVIORS

Everyone has breathing habits. Most people are NOT aware of their breathing habits and how they may be interacting with other complaints, symptoms, and deficits. This checklist has been designed to serve as a "guideline" for assisting you in exploring whether or not your breathing habits are consistent with optimal respiration, and if not, how they may be affecting you at specific times and places.

Name ______ **Date** ______ **Email** ______

Tel ______ **Sex** ___ **Age** ___ **Primary health issue?** ______

Is there a breathing issue? ______

Answers to the following questions are important to learning about the possible origins of your breathing habits.

- ☐ YES ☐ NO Issues related to breathing? ______
- ☐ YES ☐ NO Episodes of not being able to get enough air? ______
- ☐ YES ☐ NO Respiratory disorders? ______
- ☐ YES ☐ NO Physical injuries: e.g., back, chest, neck? ______
- ☐ YES ☐ NO Emotional issues: e.g., panic, anxiety, anger? ______
- ☐ YES ☐ NO Life traumas: e.g., PTSD, emotional abuse, chronic stress? ______
- ☐ YES ☐ NO Pain issues: past or present, acute or chronic? ______
- ☐ YES ☐ NO Physical limitations: e.g., fatigue, speech, movement? ______
- ☐ YES ☐ NO Deficiencies: e.g., electrolytes (kidney problems)? ______
- ☐ YES ☐ NO Social challenges: e.g., relationships, family? ______
- ☐ YES ☐ NO Work related challenges: e.g., co-workers, supervisor? ______
- ☐ YES ☐ NO Learning issues, e.g., attention, memory, focus? ______
- ☐ YES ☐ NO Performance issues: e.g., speaking, technology, testing ______
- ☐ YES ☐ NO Current prescriptions? ______

Do you ever experience any of the 14 symptoms listed below? Check the **Y column** for "YES," **OR** the **N column** for "NO," after each symptom listed. If you checked YES, indicate *how frequently you experience the symptom* by checking a number 1 through 7, where 1 is rarely and 7 is every day. Then enter in the *situations in which you experience a symptom,* in the "situation column," by entering a number that corresponds to one of the 15 situations listed at the bottom of the page. If the situation is not shown on the list, write it into the "comment" column. Focus on when, where, and with whom these symptoms may occur.

How often? 1 = rarely .... 7 = every day

Do you experience the following? If so, how often?	*N*	*Y*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*Situations*	*Comment*
Chest tightness, pressure, or pain											
Intentional breathing, purposeful regulation											
Dizziness, light-headedness, fainting											
Shortness of breath, difficulty breathing											
Tingling or numbness, e.g., fingers, lips											
Unable to breathe deeply											
Not exhaling completely, aborting the exhale											
Deep breathing, like during talking											
Chest breathing, effortful breathing											
Breath holding, irregular breathing											
Rapid breathing, panicky breathing											
Worried about my breathing											
Mouth breathing											
Can't seem to get enough oxygen											

***SITUATIONS**: **circumstances under which you experience the above symptoms**

(01) working (employment)
(02) resting (between tasks)
(03) performing (e.g., test taking)
(04) feeling anxious or worried
(05) feeling tired or stressed
(06) interacting in groups
(07) traveling, unfamiliar places
(08) socializing, meeting people
(09) feeling angry or upset
(10) intimacy, expressing feelings
(11) physical discomfort, pain
(12) going to sleep, while asleep
(13) learning new tasks, new info
(14) feeling unsure of self
(15) allergens, weather, foods

General comments: ______

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