Respiration

The Complete Pocket Guide

iMotions – Unpack Human Behavior

What's inside?

The complete pocket guide to respiration

Everything you need to know

Breath in. Breath out. We're all performing respiration all the time - but there's more to this basic function than you might first think. The activity of our respiratory system relates to our experience in the world, and it changes as our experience changes. We can derive information about how we feel just be examining these breaths.

In essence, respiratory tracking pertains to the measurement of breathing. More specifically, it involves the recording of chest and abdominal movements in an environment, utilizing sensors or other methods to assess respiration. While the concept of respiratory tracking is relatively straightforward, the underlying technology may seem intricate and less accessible. We'll break this down and make it clear in the coming pages.

The following pages are filled with all the essential information and helpful tools to assist you in gaining a solid understanding of respiration, respiratory tracking technology, and best practices for your own research projects.

Ready to become a expert in respiration research?

Let's get to it!

Introduction

Respiration research

The beginnings of the field

If there is one person who marked the foundation of respiration research it is Antoine-Laurent de Lavosier. In 1784, he carried out an ingenious experiment - using ice packs, a burning piece of charcoal, and a guinea pig - that established some of the first scientific properties of respiration (Karamanou and Androutsos, 2013). Specifically he found that respiration is similar to combustion - a process that both consumes oxygen and gives off heat. While a full account of his work is impossible, one of his most interesting findings concerns how respiration changes with behavior. Without knowing it, Lavosier marked the beginning of respiration research among human behavior scientists.

Respiration and human behavior research

Respiration is a crucial method in human behavioral research as it provides insight into physiological and psychological states. Changes in respiration rate, depth, and patterns can indicate stress, arousal, or emotional responses. Monitoring respiration helps researchers understand how individuals react to various stimuli, contributing to a deeper comprehension of human behavior. Today, respiration is used as a method in many fields of human behavior research, including emotion research, cognitive science, clinical applications and exercise research. It is often examined together with sensors that monitor heart rate (ECG), skin conductance (electrodermal activity, EDA) and brain activity (EEG) to augment insights into emotions, behavior, and cognitive states. Sometimes respiration signals are necessary for accurately interpreting the data collected by other sensors. For example, when people take a deep breath, it will lead to a strong EDA response although it may be unrelated to the affective component of sweat release (Azad et al., 2018). Through this perspective, respiration provides not only insight into a person's emotional, behavioral, and cognitive states but also aids researchers in accurately interpreting their biosensor data.

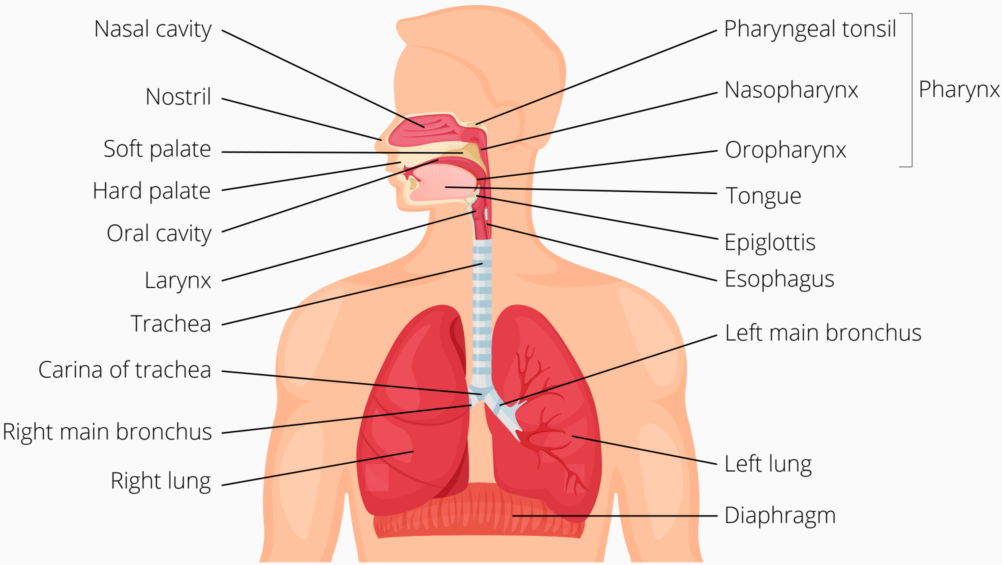
Although respiration research has been published since at least the end of the 17th century, it still continues to advance in modern times. Some of the recent improvements include developing wearable technology, and webcam-monitoring that offers continuous, non-invasive monitoring. Further, the integration of artificial intelligence (AI) and machine learning is contributing to the ongoing development of personalized medicine and healthcare.

The biology of respiration

How we breathe

Anatomy serves as the foundation for understanding the intricacies of the human respiratory system and the mechanisms that govern the fundamental process of breathing. The human respiratory system comprises several essential components that work together seamlessly to facilitate the exchange of oxygen and carbon dioxide, crucial for sustaining life.

- Nasal Cavity and Pharynx: The journey of inhaled air begins in the nasal cavity and pharynx, where air is filtered, humidified, and warmed before it travels deeper into the respiratory system.
- Trachea and Bronchial Tree: The trachea, or windpipe, splits into the bronchial tree, leading to the lungs. These airways are lined with cilia and mucus to trap and expel harmful particles, safeguarding the delicate alveoli within the lungs.
- Alveoli and Gas Exchange: At the smallest level of the respiratory system, the alveoli are responsible for the crucial exchange of oxygen and carbon dioxide with the bloodstream. This process is essential for providing oxygen to the body's cells and removing waste carbon dioxide.



The mechanisms of breathing are orchestrated by a complex interplay of physiological processes:

- **Inhalation and Exhalation:** Breathing is a dynamic process involving the contraction and relaxation of respiratory muscles. During inhalation, the diaphragm contracts, and the chest cavity expands, drawing air into the lungs. Exhalation is the passive process of air being expelled as the muscles relax.
- **Respiratory Muscles:** The diaphragm and intercostal muscles are the primary actors in this performance. They work harmoniously to change the volume and pressure within the thoracic cavity, allowing air to flow in and out.
- **Control by the Nervous System:** Breathing is intricately regulated by the autonomic nervous system, with centers in the brainstem continuously monitoring oxygen and carbon dioxide levels in the blood. These centers adjust the rate and depth of breathing to meet the body's changing demands.

Lastly, various factors influence the efficiency of respiration:

- **Oxygen and Carbon Dioxide Levels:** The body's need for oxygen and the removal of carbon dioxide are tightly regulated. If oxygen levels drop or carbon dioxide levels rise, the body responds to restore equilibrium.
- **Lung Compliance and Elasticity:** Lung tissue must be both compliant, able to stretch and expand, and elastic, capable of returning to its original shape. Changes in these properties can affect lung function.
- **Lung Volume:** Lung volume, such as vital capacity and tidal volume, influence the amount of oxygen and carbon dioxide that travels through the lungs. This provides essential information about lung health and function.

Understanding the anatomy, mechanisms, and factors that influence respiration is vital for healthcare professionals, as well as anyone interested in maintaining good respiratory health and also for those who may want to understand how these mechanisms interplay with behavior and cognition. This foundational knowledge serves as a gateway to appreciating the complexities of the human respiratory system.

Respiration Measurement Techniques

Breath detection

Respiration measurement techniques can be broadly divided into three categories: non-invasive and invasive methods within healthcare, and non-invasive methods for human behavior research. The non-invasive and invasive methods within healthcare play pivotal roles in monitoring and assessing respiratory function, each serving specific purposes within clinical practice.

Non-invasive methods are favored for their simplicity and reduced risk, making them essential tools for initial evaluations and continuous patient monitoring.

- *Spirometry:* Spirometry is a non-invasive method used to measure lung function. Patients breathe into a device that records parameters like vital capacity and forced expiratory volume. It's invaluable in diagnosing respiratory conditions like asthma, chronic obstructive pulmonary disease, and assessing treatment effectiveness.
- *Capnography:* Capnography monitors the concentration of carbon dioxide in exhaled breath, providing real-time feedback on a patient's ventilatory status. It's widely used during anesthesia and in emergency medicine to ensure proper ventilation.
- *Pulse Oximetry:* Pulse oximetry measures oxygen saturation in the blood by attaching a sensor to a patient's fingertip or earlobe. It's a non-invasive and widely used method for monitoring oxygen levels, particularly in critical care settings.

In contrast, **invasive methods** delve deeper into the patient's physiology. These methods are typically used in the hospital for diagnostic and critical care purposes.

- *Arterial Blood Gas Analysis:* This method involves drawing arterial blood to assess oxygen, carbon dioxide, and acid-base balance. It's indispensable in critical care to guide ventilator management and monitor patients with severe respiratory conditions.
- *Esophageal Pressure Monitoring:* Esophageal pressure catheters provide insights into lung and chest wall pressures, aiding in the assessment of respiratory mechanics. It's commonly used in intensive care and research settings.
- *Plethysmography:* Plethysmography measures changes in lung volume, helping diagnose conditions like asthma and assess lung function.

Advancements in technology have also led to the development of wearable and remote monitoring devices, more commonly used within human behavior research:

Respiration belts: One of the popular ways of measuring respiration continuously is through a respiration belt that leverages piezo-electric sensors or respiratory inductance plethysmography. The belt contains an integrated sensor which measures the displacement changes of the chest (thorax) or abdomen. The belt typically sits around a person's chest capturing the movement in the thoracic cage (for bodies with breasts, the chest band is positioned either under or over the breasts). However, the belt can also be placed around the abdomen to better capture the abdominal extension and fall. What placement is best depends on your specific study. Several hardware providers offer respiration chest bands, including Biopac and Biosignals Plux. Respiration belts tend to offer the highest signal quality in controlled laboratory settings.

Electrocardiography (ECG) and photoplethysmography (PPG):
These sensors are typically used to measure a person's heart rate and pulse, but as breathing behavior influences both of these signals it is possible to also derive respiration data from them (Ali et al., 2021).

The heart and lungs have separate rhythms and both rhythms affect how much blood is contained in each pulsation of the heart. Because both the heart and lungs are contained within the thoracic wall, movements of the lungs affect pressure on the heart and the surrounding major blood vessels. During inhalation, the lungs expand and move away from the heart. Conversely, the lungs contract and increase pressure around the heart during exhalation. These movements of the lungs cause changes in blood volume within some chambers of the heart which affects how much blood is pushed out of the heart with each beat. Because ECG and PPG track the activity of the heart chambers and the pulsations of blood vessels, respectively, this information can be used to measure respiration rate.

ECG is typically used to measure electrical activity from the heart. The signal produced can be divided into the separate actions of the chambers. Because respiration affects the activity of some chambers, algorithms can use feature detection to extract the relevant parts of the signal and infer respiration rate from them. The placement of the ECG leads can be optimized for detecting respiration, optimizing the signal from the relevant chambers. One drawback of using ECG to measure respiration is that it requires advanced data signal processing and ECG can be quite intrusive for subjects, needing to place electrodes beneath their clothing.

PPG sensors are typically placed on the finger or wrist (but sometimes placed elsewhere for more clinical applications) to measure changes in the blood flow of the skin using optic light. When the heart pumps out blood, pulsations in blood vessels reflect the rhythm of the heart and the volume of the blood passing through. (indicating heart rate and respiration rate, respectively) Thus, a frequency analysis on PPG data can reveal both heart rate and respiration rate.

Compared to respiration belts, ECG and PPG are more resistant to movement artifacts. Thus, PPG based sensors are therefore often the better choice in ambulatory settings. Many modern wearables use PPG for deriving respiration (Balban et al., 2023).

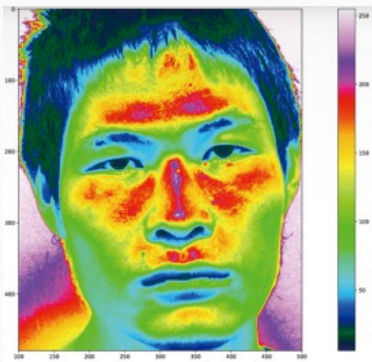
Accelerometer sensors:
Accelerometers capture movement, and they can be used to measure movement of the thoracic cage (chest) and abdomen during breathing (Ali et al., 2021). We know that during inspiration, the chest expands and the abdomen rises, while expiration correlates with contraction of the chest and fall of the abdomen. Accelerometers can be used to measure these movement patterns, which, after signal processing, can be used to derive respiration activity. While accelerometers are often markedly more affordable than respiration belts and PPG-based sensors they also come with limitations. The primary challenge is accurately extracting respiration information from the acceleration data, which requires sophisticated signal processing and algorithms. Integration with other sensors or validation against standard respiration measurement methods may be necessary to ensure accuracy and reliability in research studies.

Camera-based respiration analysis: There are three different ways cameras can be used for respiration analysis: **thermography-based**, **PPG-based, motion-based** (Wang et al., 2022). Camera-based respiration analysis is used in a variety of research fields, including apnea detection (Romano et al., 2021) and acute stress detection (Cho et al., 2019).

Motion-based camera analysis uses simple cameras to capture the respiration-induced motion at the chest and/or abdomen. Similar to the respiration belts, respiration cycles are represented by the expansion of the chest during inhalation and the subsequent relaxation during exhalation. Algorithms use feature detection to identify the chest using landmarks such as the shoulders, arms and head from the recorded video frames. Once the chest area has been identified, frames are compared sequentially to measure how much (and which directions) the chest moves from frame to frame. Filters are used to exclude chest movements that are not likely due to breathing. One major advantage of this technology is that the motion-based camera can be a simple, affordable RGB camera. Typically, this method is best for respondents that are sitting relatively still during a study and relies on good contrast between the subject and the background.

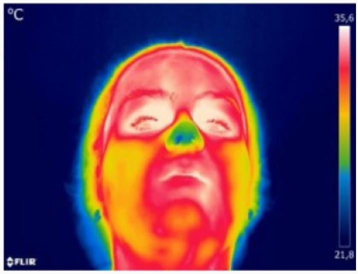
In iMotions, our web camera respiration is a motion-based camera analysis and can be used as part of a remote data collection lab. For more information visit (LINK TO TECHNICAL BLOG) or (LINK to MODULE PAGE).

Camera based-PPG (also referred to as remote PPG, rPPG) can extract respiration metrics based on blood-volume changes in the skin. Similar to PPG from sensors (discussed previously), camera-based PPG uses illumination of the skin to detect changes in blood volume in the small blood vessels in the skin. Feature detection is used to focus on certain areas of the face where it is easier to detect changes in blood flow that cause small changes in skin color. Data is extracted from the color channel data to quantify these changes. One caveat of this method is that some skin tones are more optimal than others and it can be very sensitive to the

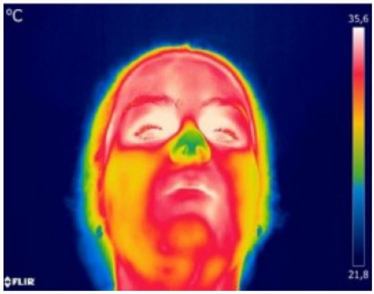


lighting of the environment (including shadows during movement).

Thermography-based respiration analysis involves using a thermal camera (infrared camera) that can capture subtle temperature changes at the nostrils and mouth as body temperature air is exhaled (and is likely warmer than the surrounding environment) and environmental air is inhaled (and is likely cooler than the air it displaces).



Nasal inspiration



Nasal expiration

Applications in Human Behavior Research

What the breath can say about behavior

Understanding human behavior and its underlying physiological mechanisms is a complex and multidimensional field of research. The study of respiration, particularly its patterns and physiology, has proven invaluable in shedding light on various aspects of human behavior and its physiological correlates.

Stress and Emotional Responses:

Respiration and Stress Physiology:

Stress is a pervasive aspect of modern life, and its impact on emotional well-being is significant. Researchers have found that stress induces specific changes in respiration patterns. Increased stress levels can trigger faster and shallower breathing, often leading to increased heart rate and heightened physiological responses (Tipton et al., 2017; Widjaja et al., 2013). Monitoring respiration in the context of stress physiology allows researchers to gain insights into the body's response to stressful situations and develop evidence-based interventions. Deep breathing and respiratory biofeedback is an emerging field that is demonstrated to help people with panic disorders as well as those struggling with physical conditions such as hypertension (Nicolo et al., 2020).

Respiratory Patterns during Anxiety:

Anxiety is another emotional response that strongly influences respiration. Studies have shown that individuals experiencing anxiety may exhibit irregular or rapid breathing patterns (Suess et al., 1980). As with stress physiology, understanding these patterns helps researchers explore the physiological mechanisms underlying anxiety and develop interventions to manage and alleviate symptoms. The development of smart clothing, such as shirts embedded with biosensors, is enabling a completely new way of assessing ecologically valid respiratory behavior among people struggling with anxiety and other mental illnesses.

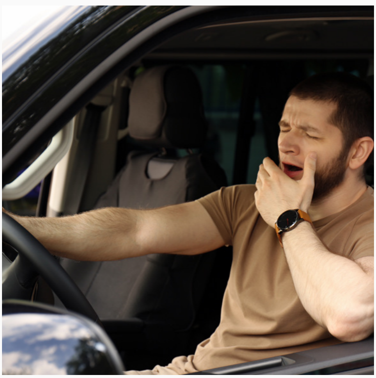
Respiration and Therapeutic Interventions:

Respiration is also used to assess the efficacy of therapeutic intervention. An interesting line of research has used respiration, among other biosensors, to address how certain scents can help reduce stress and anxiety. Two studies found that certain aromas or fruit fragrances are effective in reducing stress and anxiety in patients during medical interventions (Santang et al., 2023; Hashemina et al., 2014). In both cases, the scents and fragrances reduced the respiration rate - indicative of reduced stress and anxiety levels.

Cognitive and Mental Workload:

Respiration and Cognitive Load:

The cognitive demands of mental tasks can impact respiration. High mental workload can lead to changes in breathing patterns (Nicolo et al., 2020; Grassmann et al., 2016). Specifically, respiration frequency increases with the difficulty of the task, for example during mental arithmetic, working memory or inhibition tasks. This positive relationship also holds true during exercise: adding a cognitive task to a physical exercise increases the respiration frequency even further. The study of respiration in the context of cognitive workload provides valuable information on how the brain and body interact during tasks that require significant mental effort.



Drowsiness & Fatigue When Driving:

Respiration serves as a crucial physiological parameter for evaluating drowsiness and fatigue, particularly in the context of driving safety. When individuals become progressively drowsy or fatigued, their respiratory patterns exhibit discernible changes that can be instrumental in predicting their level of alertness. For instance, during extended periods of driving, a decrease in respiratory rate and shallower breathing may indicate encroaching drowsiness (Ebrahimian et al., 2022; Kim and Shin, 2019; Kiashari et al., 2018). Monitoring these subtle shifts in respiration provides an invaluable tool for developing fatigue detection systems in vehicles. Integrated into smart cars, such systems can alert drivers to their diminishing alertness, helping prevent accidents caused by fatigue-induced lapses in attention. By leveraging respiration as a biomarker, these technologies contribute to enhanced road safety by addressing the critical issue of driver drowsiness, a leading factor in accidents.

Breathing Patterns in Decision-Making:

Decision-making is a complex cognitive process influenced by various factors, including emotional and physiological responses. Research on breathing patterns during decision-making has revealed that deep breathing practices markedly improves their business decision making abilities (De Couck et al., 2019). This field of study can aid in understanding how physiological responses contribute to decision-making processes.

Social Interaction and Communication:

Respiratory Synchronization in Conversation:

Human interactions involve a subtle yet vital aspect: respiratory synchronization. Choir singers and their conductor synchronize their respiration during performances, which may have important implications for performance (Muller and Lindenberg, 2011). Likewise, couples synchronize their respiration during moments of empathy, and this physiological synchrony may contribute to the analgesic effects of interpersonal touch (Goldstein et al., 2017). This type of research helps us better understand how social interactions influence and improve our behavior, including communication effectiveness and social support.

Nonverbal Communication through Breathing:

Beyond synchronization, the nuances of breathing also play a role in nonverbal communication. Changes in breathing patterns, such as sighing or breath-holding, can convey emotions or reactions that may not be explicitly expressed through words (Ramirez, 2014). Investigating these nonverbal aspects of breathing enhances our understanding of human social interactions.

Physical Activity and Exercise:

Respiration and Exercise Intensity:

The relationship between respiration and physical activity is well-documented. As exercise intensity increases, respiration rate and depth often follow suit to meet the heightened oxygen demands (Nicolo et al., 2017). Researchers examine how respiration adapts during exercise, aiding in the assessment of physical performance and the development of training regimens, yet respiration is often overlooked by coaches and other professionals focused on enhancing performance (Nicolo et al., 2020).

Breathing Patterns during Physical Tasks:

Beyond exercise, everyday physical tasks also elicit distinctive breathing patterns. Studying these patterns provides insights into how respiration supports and adapts to various activities, from lifting objects to climbing stairs, and contributes to our understanding of the body's response to physical demands.

Conclusion

In sum, the study of respiration in the context of human behavior research is a rich and multifaceted field, offering a window into the intricate connections between physiological responses and various facets of human experience, from emotional and cognitive processes to social interaction, physical activity, and more. Researchers continue to uncover the profound ways in which respiration reflects and influences human behavior.

Signal Processing

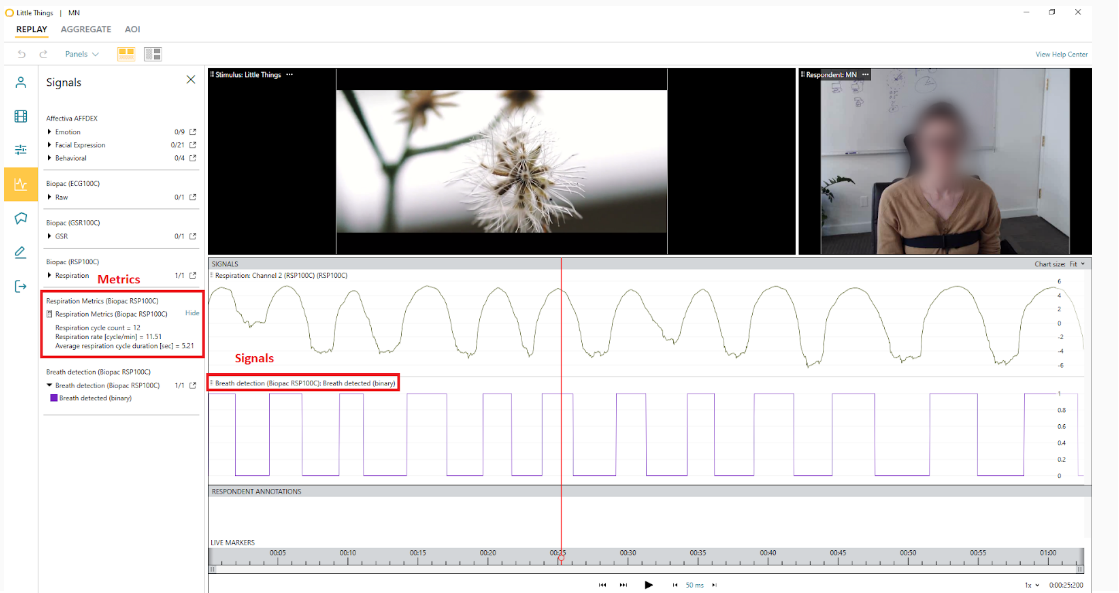
Respiration data

Understanding the results

Signal processing on respiration data from humans is essential for improving signal quality. It helps filter out noise, artifacts, and interference, ensuring accurate and reliable data for diagnostic and monitoring purposes. This high-quality data is crucial for researchers to accurately understand their data and for healthcare professionals to make informed decisions and provide effective care.

Researchers process respiration data using several common techniques. First, they often employ digital filtering to remove noise and artifacts, ensuring the purity of the respiratory signal. Signal segmentation is crucial, as it involves identifying individual breaths and their characteristics. Time-domain analysis quantifies parameters like respiratory rate and variability, while frequency-domain methods, such as Fourier analysis, reveal frequency components in the signal. More advanced approaches, like wavelet transforms, assess both time and frequency information simultaneously. Researchers also use machine learning algorithms to classify and predict respiratory patterns and anomalies. Combining these techniques, they gain valuable insights into respiratory patterns and human behavior.

In iMotions, the respiration signal is processed by a Bandpass Butterworth filter. Think of filtering like adjusting the radio to get a clearer signal. In this case, it removes unwanted frequencies from the respiration signals, and there's an option to add another filter to remove specific interference. The iMotions R notebook then looks for peaks in the respiration signal, which indicate a full breath.



After the signal processing, you will be able to visualize the processed breath detection signal and the raw signal in the replay. The detected respiration peaks represent where amplitudes are above a predefined threshold. Detected peaks are assigned a value of “1”. Signals that are below the defined threshold are assigned a value of “0”.

All of the metrics are summarized in the signals tab and include the respiration cycle count, the respiration rate (cycle/min), average respiration cycle duration (sec). Each signal, and its interpretation, is described in the next section.

Respiration Metrics and How to Interpret them

This section dives into the respiration metrics that you can access in iMotions, an overview of respiration rates to expect in typical/healthy populations, and what to consider when interpreting your data.

Once signal processing is completed, iMotions provides three output metrics:

- Respiration cycle count
- Respiration rate (cycle/min)
- Average respiration cycle duration (sec)

Let’s dig into each of them.

Respiration cycle count reflects the number of cycles within the displayed stimulus for each respondent. This metric is useful if you are interested in knowing how many breath cycles a person experienced during a stimulus without normalizing for the duration of time.

Average respiration cycle duration refers to the average amount of time each respiration takes during a certain stimulus. Each average respiration cycle duration is measured in seconds. Respiration cycle duration is an invaluable metric for several research fields, including the development of anxiety/stress interventions, evaluations and treatments for sleep apnea as well as exercise research.

Respiration rate is the normalized number of breaths a person takes during a stimulus, and is measured as the number of cycles per minute (cycle/min). Respiration rate, also referred to as respiration frequency is one of the most well studied and important metrics when tying together respiratory behavior and emotional/behavioral states. Of all of the respiration metrics, respiration rate is one of the most sensitive to emotional stressors (Nicolo et al, 2020). Respiration rate, compared to the volume of our breath, is directly regulated by different parts of our brain including areas involved in motor control, emotion and cognitive processing. In fact, respiration rate typically increases in proportion with the emotional stress or cognitive load a person experiences, making respiration rate a valuable measure of the human experience (Nicolo et al, 2020; Ma et al., 2017; Grassman et al., 2016).

Normal respiration rates

To interpret respiration data, it is helpful to compare it to norms.

For a resting adult, respiration rate varies from 12-20 breaths per minute. Under maximum exertion, the respiration rate typically hits 50 breaths per minute. In athletes the maximum respiration rate can reach 60 breaths per minute.

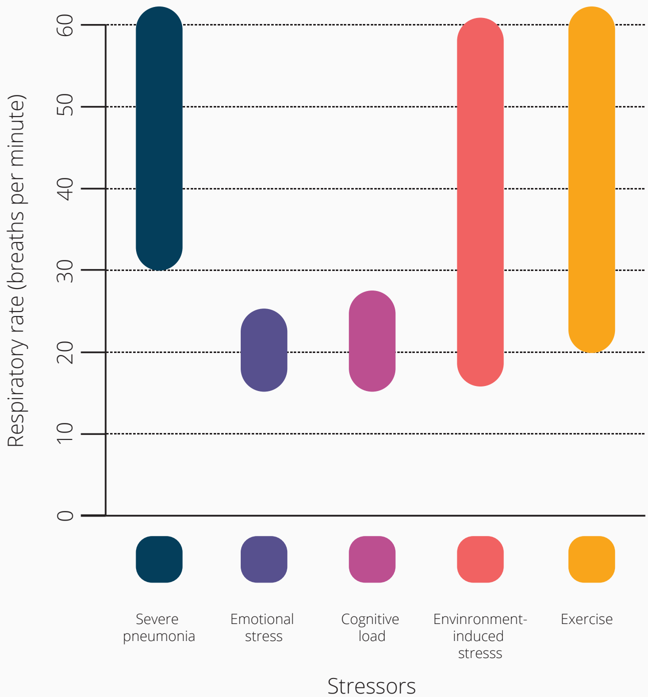
For children, the respiration rate is higher and continues decreasing till they reach 18 years of age. The steepest decline occurs in the first two years of life where the respiration rate decreases from a median of 44 breaths/minute to 26 breaths/min by the age of two. According to the CDC the following chart reflects a child's respiration rate over the course of their development.

Age	**Respiratory rate (per minute)**
1 month	40-60
6 months	25-40
1-3 years	22-30
4-6 years	20-24
7-9 years	18-24
10-13 years	16-22
14-18 years	14-22
>18 years	12-20

The complexities of interpreting respiration data

While respiration data can give powerful insights into an individual's emotional, physical and behavioral state, it is important to always consider the context that the results are measured in (Nicolo et al., 2020). For example, the range of respiration rate changes associated with emotional stress and cognitive load are highly overlapping, and without knowing the context of the stimuli it is nearly impossible to infer which behavioral state thay may experience. Of course, combining the study with other sensors such as heart rate sensors and electroencephalogram (EEG) endows a researcher with a much greater understanding.

Another poignant example is the difficulty of dissociating a high respiration rate due to intense physical exercise, compared to severe pneumonia or environment-induced stress. Again, knowing the context (is the person sick, are they moving around and exercising, or are they in an area with high chances of environmental stress) will be critical for the final interpretations. Sensors such as accelerometers, eye tracking, voice sensors, and electrodermal activity (EDA) sensors are all critical in making accurate interpretation of the respiration data.



Equipment and data collection recommendations

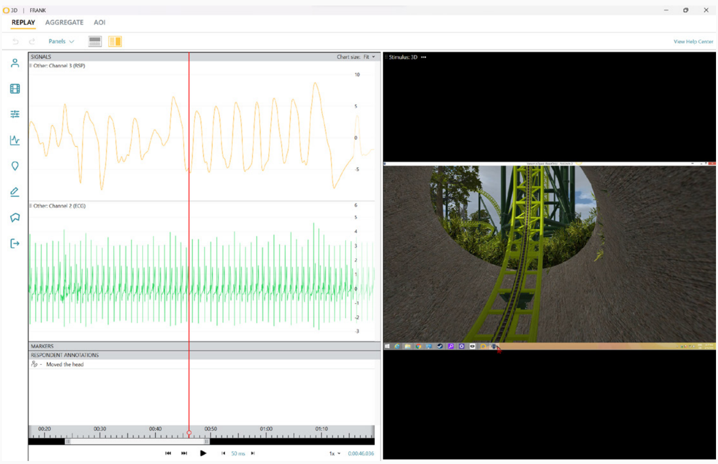
Best practices for respiration research

The quality of your respiration data will depend on your experimental design and the hardware you use. Some sensors are created to be more resistant to movement, while others have higher accuracy but greater sensitivity to movement artifacts. Below we cover some of the important considerations as you design your study.

Software and hardware

- **Hardware that you need:** with the technological developments, respiration sensors come in many non-invasive forms that necessitate minimal nuisance to the participant. These sensors can range from belts, to wristbands to contact-less video recordings. The specific sensor that you choose for your study will determine what additional hardware you may need.

- **Software that you need:** some respiration sensors come with their own software to start/end a recording, replay functions, and in some cases, data analysis abilities. If the software includes data analysis, then it is important to consider how they perform signal processing and calculate the respiration metrics. How the data is processed highly impacts your final results. Moreover, you want to consider whether you want to synchronize your respiration data to the signals from other sensors.



Experimental design

Respiration sensors are versatile and can be used both within and outside of the laboratory. However, you still need to consider how your study design can influence your data.

Placement of the sensor:

If you decide to purchase a respiration belt, then you will have to consider where to place it. A respiration belt is typically placed around the chest to monitor and measure a person's chest movements during respiration. This type of belt can be used to monitor breathing rate and patterns, as well as to assess the effort and depth of breathing.

Alternatively, a respiration belt can be placed around the abdomen to monitor abdominal breathing, which is often used in certain clinical or research settings to assess breathing patterns or for biofeedback purposes.

The choice of whether to place the belt around the chest or the abdomen depends on the specific goals of the monitoring or measurement and the context in which it is being used. Both chest and abdominal belts have their applications, and the choice should be based on the specific needs of the

Speaking during respiration recordings:

In most cases, it is best to minimize speaking during respiration recordings to ensure accurate and consistent data. Speaking can introduce variability and artifacts into the recorded respiration patterns, making it more difficult to analyze and interpret the data. However, there may be situations where speaking is necessary or unavoidable during a respiration recording. In those cases, it is appropriate to have a way to recognize speech events, for example by recording the voice, and then exclude the respiration periods overlapping with speech, or, alternatively, analyze them separately.

Standing vs sitting:

Collecting respiration signals in a sitting or standing position can lead to slightly different data due to the impact of posture on breathing mechanics. The postural change can also affect the placement of the sensor and thus the final data output.

Here are some key differences to consider when collecting respiration signals in these positions:

- *Diaphragm engagement:* When sitting, people often engage their diaphragm more than when standing. This can affect the depth and pattern of breathing. In a standing position, the diaphragm may have to work slightly harder to support breathing.
- *Chest expansion:* When sitting, the chest may expand differently compared to standing, which can affect chest wall movements during respiration. This variation in chest expansion can influence the respiration signal.
- *Postural changes:* Standing and sitting involve different postural changes in the body, which can impact the alignment of the ribcage and diaphragm. These postural differences can affect how air moves in and out of the lungs.
- *Motion artifacts:* Standing typically involves more body motion than sitting, so collecting respiration signals while standing may introduce more motion artifacts into the data, which can make the analysis more challenging.
- *Comfort and relaxation:* Individuals may feel more comfortable and relaxed in one position over the other, which can affect their breathing patterns. This comfort factor can influence the respiration data collected.

In research or clinical settings, it's essential to consider the specific goals of the respiration signal collection and choose the position that is most appropriate for the study or assessment. In some cases, researchers may collect data in both sitting and standing positions to account for these differences and obtain a more comprehensive understanding of an individual's respiration patterns. The choice of position should align with the research question or clinical assessment being conducted, and the final decision should be preceded by pilot tests.

Conclusion

In essence, respiration stands out as a pivotal metric in human behavior research, providing deep insights into both physiological and psychological states. Its significance becomes apparent in its role in stress, emotional responses, cognitive load, and various behavioral dimensions. The foundational knowledge of respiration opens a pathway to understanding human respiratory health, and contemporary technology amplifies the capabilities of research.

A spectrum of measurement techniques, ranging from traditional spirometry to advanced wearable devices and non-contact camera-based analysis, offers versatility in experimental design. Respiration research has become a forefront sensor, embraced by academics and industry alike, for capturing diverse human behaviors. Academics and companies are harnessing respiration metrics to detect and predict individuals' health status and cognitive states. Collaborating with other biosensors and utilizing artificial intelligence (AI), respiration plays a pivotal role in shaping the future landscape of human behavior research.

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Copenhagen, Denmark
Kristen Bernikows Gade 6
4th floor
København K, 1105
TEL: +45 71 998 098

Boston, USA
38 Chauncy Street
Floor 8, Suite 800
Boston, MA 02111
TEL +1 617-520-4958

China
No- 1 Fortune Avenue
Room 2902
Yubei District, Chongqing
TEL +886 931684806

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