

Biology 347 General Physiology Lab

Advanced Cardiac Functions

Blood Pressure, Heart Rate, and Vagal Tone

Objectives

- Students will interpret heart rate and blood pressure data as it relates to vagal tone
- Students will define and understand the term vagal tone.
- Students will conduct experiments that monitor blood pressure and heart rate while under a mild cognitive stressor.

Introduction

Heart rate is the number of beats per minute of the heart (BPM) and it is determined by factors intrinsic to the heart, as well as regulatory pathways from the brain and hormonal signals from the adrenal gland. Once again, when the brain is involved, psychological states may show themselves in the peripheral response.

Factors intrinsic to the heart include pacemaker cells (SA node cells) which discharge electrical signals to the heart muscle in order to initiate the heart beat. Sometimes these signals become disordered and the heart may beat irregularly. You've probably all seen media examples of dramatic efforts to restore a normal heart beat in the emergency room with a defibrillator. The defibrillator can sometimes stabilize a chaotic or irregular heart rhythm or it can sometimes restore a heart beat when it has ceased.

The obvious purpose of the heart beat is to move blood around the body. The rate of the heart beat is one factor which influences cardiac output and the volume and speed of delivery of the blood to body cells. Clearly, there are times when the blood needs to reach those cells more or less quickly. Exercise, responding to stressors, and even just standing up may create greater cellular needs for oxygen and blood nutrients (mainly glucose). Relaxation, sleeping and other vegetative states generally create a reduced cellular need. Sensors in the brain stem and hypothalamus provide feedback regulation of the heart rate to meet the demands of body cells. Responding to stressors involves the activation of higher limbic system structures such as the amygdale and hypothalamus, which then send signals via the autonomic nervous system to increase (or decrease) the heart rate. Neurotransmitter signals from the sympathetic branch (norepinephrine) increase the heart rate (by binding to beta1-adrenergic receptors), while neurotransmitter signals from the parasympathetic branch (acetylcholine) decrease the heart rate (by binding to muscarinic cholinergic receptors).

There are individual differences in the resting heart rate which are related to genetics, gender (females generally have faster heart rates than males), and to physical condition (state of health as well as fitness). Also, there are individual differences in the size (and sometimes the direction) of the adaptive changes which take place to environmental events. Some of these differences are related to personality, psychological state, and perhaps fitness as well.

When the heart beats it pumps blood through the circulatory system (arteries, arterioles, capillaries, venules, veins) to deliver blood to cells. The elements of the circulatory system are composed of smooth muscle cells and membranes to contain the blood. In its progress around the body, the nutritive elements are transported out of the blood to cells and the waste products of cells are transported into the blood for elimination from the body. The blood vessels exert a certain pressure on the blood, which depends in part on their elasticity and in part on neural and hormonal signals to the vessels. The elasticity of the blood vessels is limited by the buildup of plaque (lipid/protein/immune cell deposits in the walls of the blood vessels) and elasticity generally decreases with the presence of certain lifestyle factors (diet, alcohol, smoking, lack of exercise) and with age.

Blood pressure is measured non-invasively with a sphygmomanometer. A pressure cuff is placed around the upper arm and inflated while the heart sounds (Korotkoff-sounds) are monitored. The cuff is inflated to occlude the flow of blood to the arm and then deflated slowly to determine two values. The first value is the amount of pressure in the cuff when the heart sounds actually the turbulence of the blood as it rushes through the now open artery) are first heard in the arm after being occluded. This is termed the *systolic blood pressure* (SBP). The SBP is the pressure the arteries exert on the blood flow when the heart ventricles are contracting. The second value is the amount of pressure in the cuff when the heart sounds in the arm are gone and it is termed *diastolic blood pressure* (DBP). The DBP is the pressure the arteries exert on the flow of blood when the ventricles are relaxing and being filled by the atrial contractions. The blood pressure is reported in pressure units of mmHg and a typically normal blood pressure for a young person is about 120/80 (SBP/DBP).

Blood pressure is just another one of several factors which determine the delivery of blood to the cells. As in heart rate, the blood pressure is determined in part by factors intrinsic to the blood vessels themselves (elasticity) and by regulatory neural signals from the brain and hormones from the adrenal glands and kidneys. Obviously, if you want to move a substance quickly to the place where it is needed it is of value to be able to increase the rate of beating of the pump and the pressure on the contents of the delivery system. The neural and hormonal control of blood pressure is a complicated orchestration of constriction and dilation of vascular beds to achieve the adaptive delivery of blood to tissues in need.

Cardiovascular responses have been studied most often in the context of arousal and emotional states. The stress response (“fight or flight”) is a physiologically adaptive set of bodily changes in the presence of a life threat or a threat to one’s self worth. In general, activity of the sympathetic nervous system is enhanced, bringing about elevations in heart rate and blood pressure necessary to deal with the perceived threat. These responses are adaptive in the short term and generally improve human performances which require speed, strength, and endurance. Human performance which requires fine motor skills or complex cognitive processes is generally affected in a curvilinear fashion; performance is enhanced with moderate or optimal levels of the stress response, but hindered with high levels of the stress response (as anyone who plays the piano knows).

Studies have shown that anxiety, frustration, anger, fear, anticipation of pain and other negative emotional states can bring about elevations in heart rate and/or blood pressure. Positive emotional states of excitement, joy, and interest can also bring about elevated cardiovascular responses. There are, however, individual differences in the nature and the extent of cardiovascular responses in emotional states. Some of these differences stem from the nature of the individual and some stem from the nature of the environmental demands. Complicating the picture is the fact that heart rate and blood pressure may disassociate in response to environmental events. Research has supported the idea that tasks which require environmental intake or monitoring, cause heart rate lowering (blood pressure may rise or remain unchanged), while tasks which require environmental rejection (events which are aversive or bring about escape motivations) result in heart rate and blood pressure elevations. Similarly, it has been shown that tasks which tend to produce anxiety and self-focus (for example giving a speech if you have presentation anxiety) tend to elevate heart rate and blood pressure, while tasks which tend to produce anxiety and environmental-focus (for example listening to a lecture that you will be tested on later) tend to reduce heart rate while blood pressure may elevate or remain unchanged.

There are many complexities in the cardiovascular research literature and also many controversies. One interesting controversy deals with the degree to which physical fitness can perhaps mute the stress response to a psychosocial stressor. Physical conditioning of an aerobic nature has been shown in some experiments to reduce the stress response (or enhance recovery to pre-stress values) to a cognitive stressor task such as mental arithmetic. In other experiments, the baseline values are lower in persons who engage in aerobic activities, but the change over baseline is shown to be about the same as in persons who are not physically active. Sports psychologists have conducted many experiments on this aspect of psychophysiology.

The parasympathetic nervous system influences the tonic or resting heart beat by means of signals from the tenth cranial nerve, the Vagus. Even at rest, a person’s heart rate will fluctuate with his or her breathing cycle. Inspiration triggers an increase in heart rate, but this increase occurs after maximum inhalation. The latency between maximum inhalation and maximum heart rate is the time required for receptor (stretch, baro-, pH, O₂, CO₂) signals in the organ systems to be integrated, motor signals to be generated in control centers, and impulses to be delivered to effector organs (cardiac, skeletal, and smooth muscles). Conversely, expiration triggers a decrease in heart rate.

The change in the heart rate that results from breathing is known as respiratory sinus arrhythmia (RSA). The extent of the RSA is a rough measure of Vagal control over the resting heart beat, referred to as Vagal tone. The size of the RSA (degree of variability of the heart rate for each respiratory cycle) is what is determined by the Vagus nerve. When the heart rate varies considerably for each respiratory cycle, then we say there is good or high Vagal tone. When the heart rate is relatively steady with low variability for the respiratory cycle, we say there is poor or low Vagal tone. In general Vagal control over the heart rate lessens during stressful experiences when sympathetic activity is heightened, thus allowing the heart rate to rise to meet the challenge.

Vagal tone has been related to temperament (the innate “building blocks” of personality) and stress vulnerability in children. Children who show behavioral inhibition in novel situations (somewhat comparable to shyness) have low Vagal tone as evidenced by higher and less variable resting heart rates. Preschoolers who fail to show emotional expression also have low Vagal tone and are vulnerable to later depression and anxiety. There is also evidence that adults who are

extremely shy or behaviorally inhibited have higher and less variable resting heart rates. Also adults with high Vagal tone may have lower blood pressure responses to stress, making them less vulnerable to hypertension and coronary heart disease. Interestingly, adults with high Vagal tone are more susceptible to hypnosis. The exact relationship between the autonomic nervous system's regulation of physiological responses and personality is unknown, but many hypothesize that the innate sensitivity and reactivity of the nervous system may be the fundamental mechanism for biasing personality development and expression.

Introduction adapted from iWorx lab manual, copyright from CB Sciences Inc.

Procedure: Equipment Set-up

1. Connect the iWorx unit to the computer. Plug the plethysmograph cable into Channel 3.
2. Wrap the plethysmograph around the volar surface of the distal segment of the middle finger on your test subject.
3. Plug the DIN connector of the non-invasive blood pressure transducer into the DIN-DIN extension cable. Then plug the male end of the DIN extension cable into Channel 4 of the iWorx unit.
4. Place the blood pressure cuff around the upper portion of the left arm, between the elbow and the shoulder.
5. Start the LabScribe program.
6. Click on the **Settings** menu. Select **HeartRate-BP-LS2** from the menu.
7. Your settings should load onto the computer.

Procedure: Calibration of Equipment

1. Put the cuff of the BP-600 on the upper arm of the subject. Align the arrow on the cuff over the subject's brachial artery.
2. Type **Calibration @ 20 mmHg** in the **Mark box** to the right of the **Mark button**. Inflate the pressure in the cuff to **20mmHg** as read on the aneroid gauge of the cuff.
3. Click on the **Record** button, located on the upper right side of the LabScribe **Main** window. The signal should begin scrolling across the screen.
4. Click on the **AutoScale** button at the upper margin of the **Pulse** and **Blood Pressure** channels.
 - a. • If the signal on the **Pulse** channel is upside down when compared to trace, click on the downward arrow to the left of the channel title and select the **Invert** function.
 - b. • If the **pulse** signal is small or noisy, adjust the tension on the strap holding the pulse plethysmograph to the finger.
5. While recording, press the **Enter** key on the keyboard to mark the pressure in the cuff on the data. Record the output of the BP-600 at **20 mmHg** pressure for ten to fifteen seconds before increasing the pressure in the cuff. While recording at a pressure of **20mmHg**, type **Calibration @ 70 mmHg** in the **Mark** box.
6. As the recording continues, increase the pressure in the cuff to **70 mmHg** and press the **Enter** key on the keyboard. Hold the pressure in the cuff at this level for ten to fifteen seconds. While recording at a pressure of **70 mmHg**, type **Calibration @ 140 mmHg** in the **Mark** box. Continue recording.
7. As the recording continues, increase the pressure in the cuff to **140 mmHg** and press the **Enter** key on the keyboard. Hold the pressure in the cuff at this level for ten to fifteen seconds. Then, click the **Stop** button to halt the recording.
8. After the last measurement, release all the pressure from the blood pressure cuff. The subject should continue to relax in the supine position as he or she flexes and extends the fingers on the cuffed arm to return of blood to the arm.
9. Select **Save As** in the **File** menu, type a name for the file. Save the file.
10. Scroll to the beginning of the calibration data for the BP-600 non-invasive blood pressure transducer.
11. Use the **Display Time** icons to adjust the **Display Time** of the **Main window** to show the data collected at **70** and **140 mmHg** on the **Main window** at the same time. The required data can also be selected by:
 - Placing the cursors on either side of data required
 - Clicking the **Zoom between Cursors** button on the LabScribe toolbar to expand the segment with the four selected pulse cycles to the width of the **Main window**.
12. Click the **2-Cursor** icon) so that two blue cursors appear on the **Main** window. Place one cursor on the flat section of data collected when the pressure in the cuff was **70 mmHg** and the second cursor on the flat section of data collected when the pressure was **140 mmHg**.
13. To convert the voltages at the positions of the cursors to pressure values, use the **Simple Units Conversion dialogue window**. To access this dialogue window, click on the arrow to the left of the channel title, **Blood**

Pressure, to open the **channel menu**. Select **Units** from the **channel menu**, and select **Simple** from the **Units submenu**.

14. On the units conversion window, make sure **2 point calibration** is selected in the pull-down menu in the upperleft corner of the window. Put a check mark in the box next to **Apply units to all blocks**. Notice that the voltages from the positions of the cursors are automatically entered into the value equations. Enter the two pressures used in the calibration recording in the corresponding boxes on the right side of the conversion equations. Enter the name of the units, **mmHg**, in box below the pressures. Click on the **OK button** in the lower right corner of the window to activate the units conversion.

Procedure: Baseline Heart Rate and Blood Pressure

1. Click the **Start** button in the upper right corner. Take a 1-minute baseline pulse. Mark this recording as Baseline heart rate.
2. At the end of the baseline heart rate, Type Baseline BP in the comment field and mark the beginning the blood pressure study. Inflate the cuff until the finger pulse disappears.
3. Once the pulse wave disappears, release the cuff pressure at a rate of about **10 mmHg/second**. Continue to release the pressure in the cuff until the gauge reads **20mmHg**.
4. Click the stop button.
5. Have the subject remove the cuff from their arm. The subject should flex and extend their fingers to encourage blood circulation.
6. Save the file.

Procedure: Analysis of Baseline Heart Rate

1. Scroll through the recording and find the section of data recorded before the pressure in the cuff was blocking the pulse).
2. Use the **Display Time** icons to adjust the **Display Time** of the **Main window** to show a thirty-second, artifact-free section of the subject's pulse and heart rate while relaxing on the **Main window**. This section of data can also be selected by:
 - Placing the cursors on either side of the section of data needed.
 - Clicking the **Zoom between Cursors** button on the LabScribe toolbar to expand the segment of data to the width of the **Main window**.
3. Click on the **Analysis window** icon in the or select **Analysis** from the **Windows menu** to transfer the data displayed in the **Main window** to the **Analysis window**.
4. Look at the **Function Table** that is above the uppermost channel displayed in the **Analysis** window. The mathematical functions that are listed should include **Value1, Value2, V2-V1, T2-T1, Max, Min, and Mean**. The values for these parameters from each channel are seen in the table across the top margin of each channel.
5. Once the cursors are placed in the correct positions for determining the maximum, minimum, and mean heart rates, these rates should be recorded in Table 2.
6. On the **Heart Rate channel**, click and drag one cursor to the left margin of the data displayed in the **Analysis window**. Drag the other cursor to the right margin of the same data and measure the following:
 - **Maximum Heart Rate**. The value for **Max** on the **Heart Rate channel** is the subject's maximum heart rate
 - **Minimum Heart Rate**. The value for **Min** on the **Heart Rate channel** is the subject's minimum heart rate
 - **Mean Heart Rate**. The value for **Mean** on the **Heart Rate channel** is the subject's mean heart rate

Procedure: Analysis of Baseline Blood Pressure

1. Scroll through the recording and find the section of data recorded before, during, and after the pressure in the cuff was blocking the pulse.
2. Use the same procedures used in previous section to position the blood pressure data in the **Main** window, display the selected data in the **Analysis** window, position the cursors to make measurements.
3. On the **Pulse channel**, use the mouse to click on and drag the cursors to specific points on the recording in the **Analysis window** to measure the following:
 - **Systolic blood pressure**. To determine the subject's systolic blood pressure, place a cursor on the first pulse wave that reappears after the pressure from the cuff of the BP-600 is released. The value for **Value1** on the **Blood Pressure channel** is the subject's systolic blood pressure.

- **Diastolic blood pressure.** To determine the subject’s diastolic blood pressure, place the other cursor on the first of the largest pulse waves that reappear as the pressure from the cuff of the BP-600 is released. The value for **Value1** on the **Blood Pressure channel** is the subject’s diastolic blood pressure.
- **Pulse pressure,** or difference between the systolic and diastolic pressures. To measure the pulse pressure, leave the cursors used to measure the systolic and diastolic pressures. The value for **V2-V1** on the **Blood Pressure channel** is the subject’s pulse pressure.

4. Record the values for these pressures in Table 2.

Procedure: Mild Cognitive Stressor

1. Ask the subject to sit quietly as the rest of your group prepares for this exercise.
2. The mild cognitive stressor that will be used in this exercise is spelling backwards. Alphabetized lists of five-letter words to be used in this exercise are located in Table 1.
3. Select twelve words at random from the Task A list before the exercise begins. Words from the Task A list are paired with similar words from the Task B list. For example, if you select “above” from Task A list, then you must select its mate “abide” from Task B list. Note the twelve words from each list.
4. Designate a member of the lab group to speak the words to the subject during the tasks, and another member of the group to record the words misspelled by the subject in each task.
5. Before beginning the exercise, inform the subject of the experimental conditions:
 - Task A will be performed first. In Task A, the subject will spell the twelve words selected from the “A” list in a forward manner, as printed.
 - In Task B, the subject will spell the twelve words from the “B” list in a backward manner. The words from the “B” list are paired with the words selected from the “A” list. The words from the “B” list should be spoken in the same order as the mated words from the “A” list.
 - The words in each task will be spoken by a member of the lab group at five-second intervals, whether the subject has finished the spelling of the previous word or not. Since each task contains twelve words, each task will last one minute.
 - Another member of the lab group will keep track of the number of words spelled in error in each task, whether forward or backward. Spelling of a word that is not completed before the next word is spoken is considered to be misspelled.

Table 1: Five Letter Words for Tasks A and B

| Task A Spell Forward | Task B Spell Backward | Task A Spell Forward | Task B Spell Backward |
|-------------------------|--------------------------|-------------------------|--------------------------|
| above | abide | maple | mouse |
| adopt | adult | niche | nickel |
| ahead | alarm | nectar | novel |
| barge | batch | prowl | pearl |
| bread | brain | pride | prune |
| cable | candy | rusty | rowdy |
| champ | chief | realm | rafter |
| clean | clear | rapid | ruler |
| derby | deuce | sound | sober |
| dough | dozen | smock | smart |
| dream | drive | start | stomp |
| earth | empty | shawl | shock |
| event | exert | tramp | tackle |
| frame | frost | treat | truck |
| flour | flack | table | truth |
| growl | grant | wrath | whack |
| house | heart | water | worth |
| joust | juror | weary | woman |
| leach | lucky | young | yours |
| learn | laugh | zeros | zebra |

6. The assumption in this exercise is that Task A will be less distressing than the Task B.
7. Click **Start** to begin recording the finger pulse of the subject. Click **AutoScale** for the **Pulse** channel to make the signal bigger.
8. Type the subject's first name and the words "Begin Task A" in the comment line to the right of the **Mark** button. Press the **Enter** key on the keyboard as the first word in Task A is spoken. Continue to deliver a new word at 5-second intervals.
9. Type the words "End Task A" on the comment line. At the end of Task A, press the **Enter** key to enter a comment on the record. Continue to record as you begin to take the subject's blood pressure. It is important to measure the subject's blood pressure as soon as possible.
10. Inflate the cuff until the finger pulse is occluded. Then, follow the procedures used above to record the subject's post-task blood pressure.
11. When the cuff is fully deflated, click **Stop** to halt the recording process.
12. Ask the subject to sit quietly as the rest of your group prepares for the next task. Begin Task B as soon as possible.
13. Click **Start** to begin recording the finger pulse of the subject. Click **AutoScale** for the **Pulse** channel (CH 3) to make the signal bigger.
14. Type the subject's first name and the words "Begin Task B" in the comment line to the right of the **Mark** button. Press the **Enter** key on the keyboard as the first word in Task B is spoken. Continue to deliver a new word at 5-second intervals.
15. Type the words "End Task B" on the comment line. At the end of Task B, press the **Enter** key to enter a comment on the record.
16. Continue to record as you begin to take the subject's blood pressure. It is important to measure the subject's blood pressure as soon as possible.
17. Inflate the cuff until the finger pulse is occluded. Then, follow the procedures above to record the subject's post-task blood pressure.
18. When the cuff is fully deflated, click **Stop** to halt the recording process.
19. Save the recording.

Procedure: Analysis of Heart Rate During Mild Cognitive Stressor

1. Scroll through the recording and locate the section of data recorded during Task A.
2. Use the **Display Time** icons on the LabScribe toolbar to adjust the time displayed on the **Main** window so that the data from the complete period of Task A can be viewed on the screen.
3. Click the **2-Cursor** icon so that two blue vertical lines appear on the **Main** window. Use the cursors to select the data from the complete Task A.
4. Click the **Analysis** icon to open the **Analysis** window. Using the same procedures as above, measure your parameters.
5. Record this data in Table 2.
6. Scroll through the recording and locate the section of data recorded during Task B.
7. Repeat Steps 2 through 6 for the data from Task B.
8. Enter this data in Table 2.

Procedure: Analysis of Blood Pressure Following Mild Cognitive Stressor

1. Find the section of recording where the subject's post-Task A blood pressure was determined.
2. Use the same procedures employed in the baseline analysis above to measure the subject's blood pressure at the end of Task A.
3. Record this data in Table 2.
4. Find the section of recording where the subject's post-Task B blood pressure was determined. Determine the subject's post-Task B blood pressure. Record this data into Table 2.

