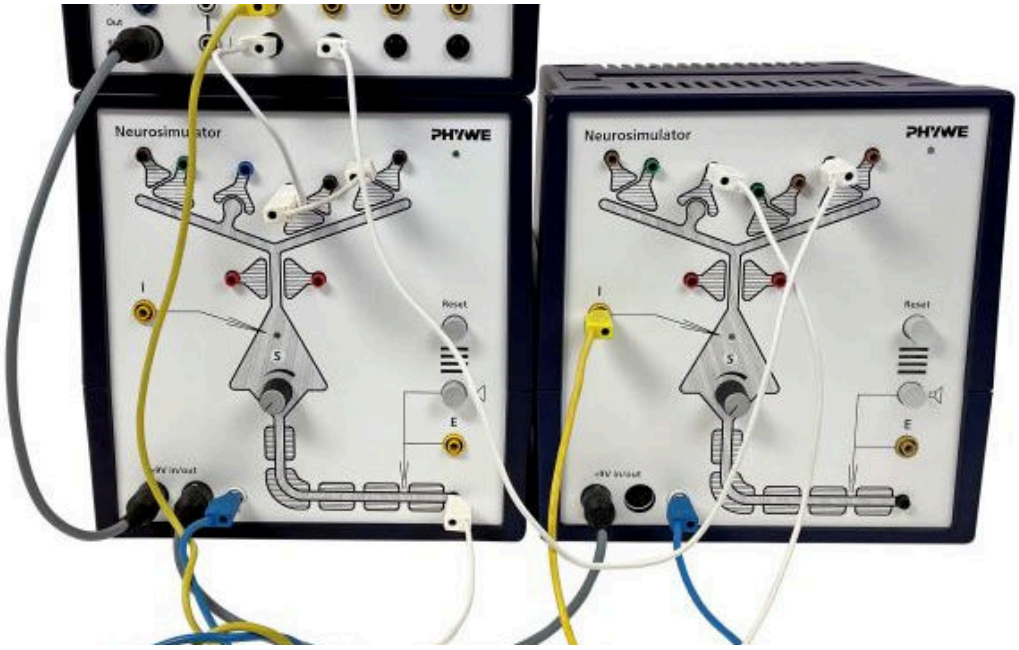
Nerve cell interactions with Cobra SMARTsense



This experiment with two nerve cells presupposes the knowledge acquired from the series of experiments with one nerve cell. The connection with a second nerve cell enables experimentation on the neuronal principles of the conditioned reflex and stimulus sequence as well as motor neuron signals with recurrent inhibition, functional characteristics of Renshaw inhibition, lateral inhibition and contrast enhancement.

Biology | Nervous system, neurobiology

Difficulty level	Group size	Preparation time	Execution time
hard	-	10 minutes	45+ minutes

This content can also be found online at:

http://localhost:1337/c/646f4256dd5ea50002439c13

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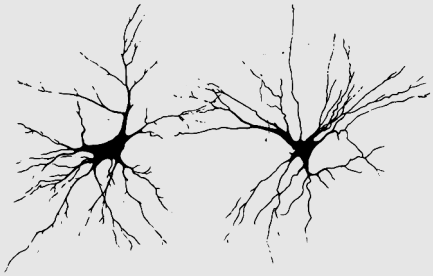

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General information

Application

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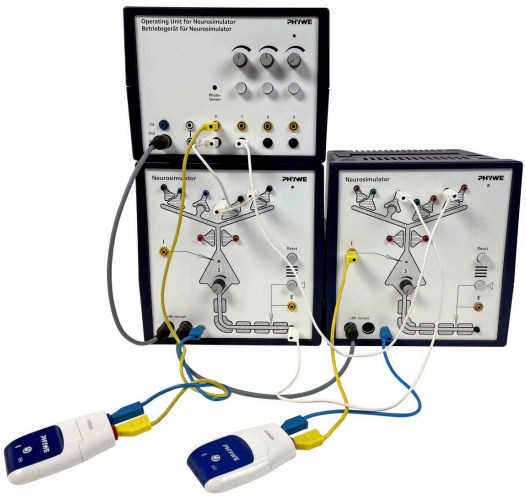

Typical experiment setup

The most important structural and functional unit of the nervous system is the nerve cell. It is primarily involved in the process of transmitting and receiving information to and from the brain.

The essential basis for the function of our brain is the communication between the nerve cells. The cells pass on their signals to other cells. Sensory impressions are processed and thoughts arise. The signal transmission takes place via so-called synapses.

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Other information (1/3)

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Prior knowledge

The experiment "The nerve cell" (P4010769) should be done beforehand.

Principle

The two voltage sensors measure the strength of the stimuli acting on the nerve cells as well as the membrane potential (EPSP) resulting from the various connections between two nerve cells.

Other information (2/3)

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Learning objective

The pupils and students learn how nerve cell interactions take place by means of important basic nerve cell interconnections.

Tasks

With the nerve function model with two nerve cells the following aspects of the interaction of two nerve cells can be investigated:

- Renshaw inhibition
- Lateral inhibition
- Neural principles of classical conditioning

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Other information (3/3)

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The power supply for the Neurosimulator supplies power for up to four Neurosimulators (neuron units) and includes three rotary switches with variable stimulus intensity and an optical sensor (this is used in the conditioning experiment, for example). To supply power to the neuron units, the 9V inputs and outputs are connected in chain. If more than four nerve cells are used, an additional power supply is necessary.

For more information on the hardware structure, see experiment P4010769 ("The nerve cell with Cobra SMARTsense").

The three experiments are presented individually in the following chapters Theory, Setup and Procudure and Evaluation, whereby the order in which the experiments are carried out can be arbitrary:

1. Renshaw inhibition
2. Lateral inhibition
3. Classical conditioning

Safety instructions

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The general instructions for safe experimentation in science lessons apply to this experiment.

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Equipment

Position	Equipment	Item no.	Quantity
1	Set Neurobiology with a nerve cell with Cobra SMARTsense	65963-22	1
2	Neurosimulator	65963-00	1

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Theory 1

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Renshaw inhibition

The **Renshaw cell**, a special neuron, protects a m**otoneuron** and the m**uscle fibre** which is driven by the motoneuron, from overexcitation. Their circuitry causes a **negative feedback** of the excitatory stimulation of the motor neuron.

The circuit can be realised with two neurosimulator modules, one representing the motoneuron and one the Renshaw cell. The stimulus for the motoneuron is amplified by spatial summation.

The Renshaw cell is also found in the spinal cord of vertebrates.

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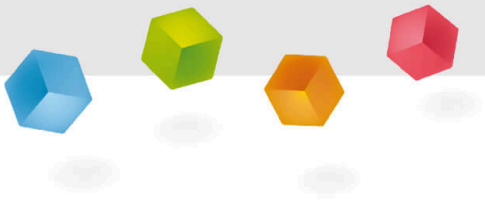

Setup and procedure 1

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Setup 1.1.1

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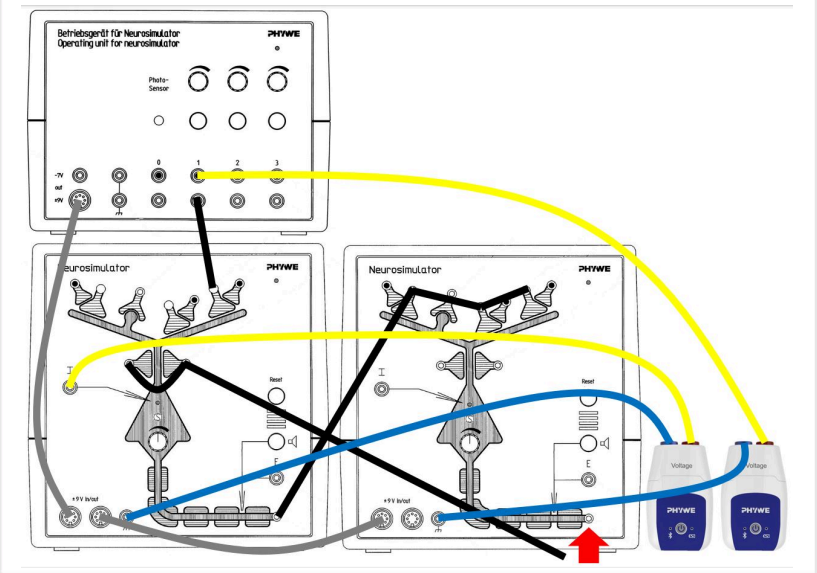
1. Motoneuron signals without and with recurrent inhibition by the Renshaw cell

Connect the power supply and the two nerve cells together as shown in the illustration. Do not plug in the end of the wire near the red arrow yet (this happens during the measurement).



Setup 1.1.2

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- Neurosimulator 1: Rotary knob firing threshold: 0%
- Neurosimulator 2: Rotary knob firing threshold: 0%
- Power supply: Rotary knob stimulus intensity: 100%

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Procedure 1.1

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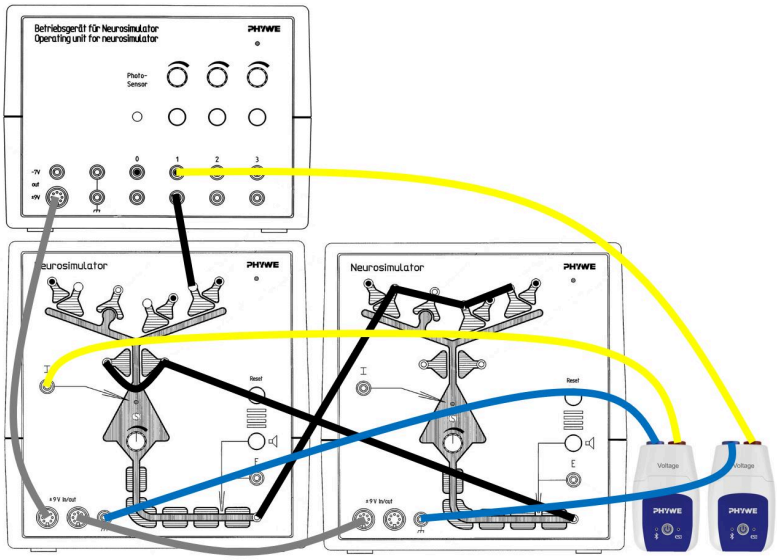
- Start measurement and press stimulus button 1 for about 3 to 5 seconds. Wait until the voltage of the EPSP has reached the output value.
- Plug the loose cable into the black socket (see fig. right).
- Press stimulation button 1 for about 3 to 5 seconds.
- Stop measurement as soon as the voltage has reached the initial value.
- Save and evaluate results.



Setup 1.2

PHYWE

2. Functional characteristics of Renshaw inhibition

The experiment is set up as before. This time all the leads are plugged in.

- Neurosimulator 1: Rotary knob firing threshold: 50%.
- Neurosimulator 2: Rotary knob firing threshold: 0%
- Power supply: Rotary knob stimulus intensity: 0%

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Procedure 1.2

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- Start measurement.
- Press and hold stimulation key 1.
- Press the stimulus button steadily and after 2 seconds gradually increase the stimulus every 2 seconds. After the last step, keep the button pressed for 2 more seconds.
- Stop measurement as soon as the voltage has reached the initial value.
- Save and evaluate the result.

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Evaluation 1

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Result 1.1

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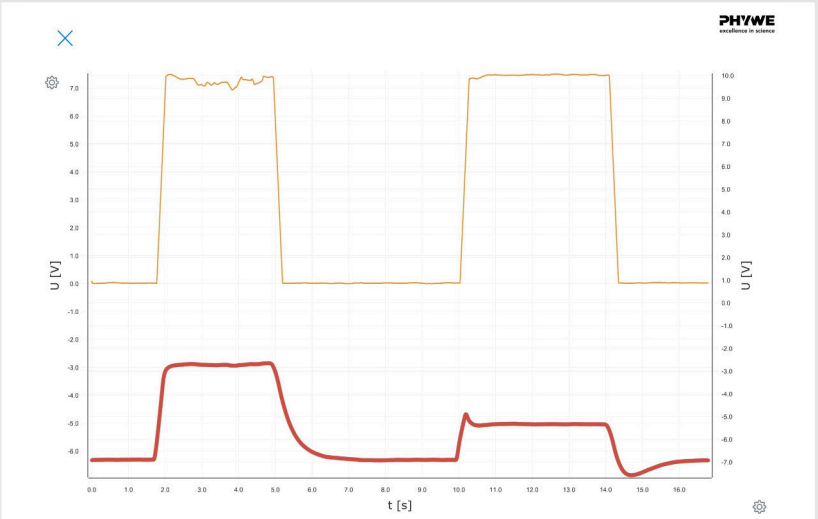
1. Motoneuron signals without and with recurrent inhibition by the Renshaw cell

Left: Motoneuron signals without recurrent inhibition by the Renshaw cell.

Right: Motoneuron signals with recurrent inhibition by the Renshaw cell.



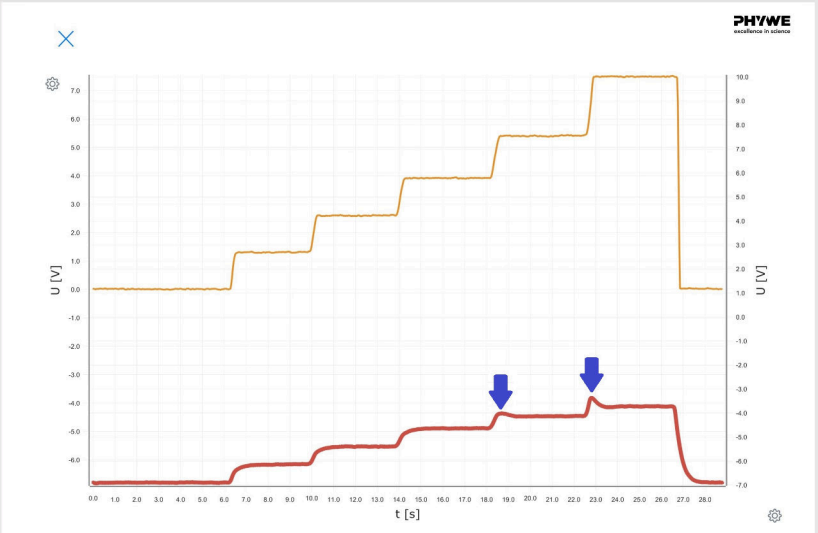
Result 1.2

PHYWE

2. Functional characteristics of Renshaw inhibition

Level 1 - 3: No inhibition at low stimulus intensities

Level 4 - 5: Significant Renshaw inhibition at higher stimulus intensities



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Theory 2

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Lateral inhibition

Lateral inhibition is a useful function of the nervous system in the brain and sensory organs. It serves to enhance differences in the stimulation of neighbouring elements and thus increase resolution. For example, it causes an improvement in the contrast between neighbouring areas in the visual system.

The following experiments can be carried out:

1. Lateral inhibition

2. Contrast enhancement

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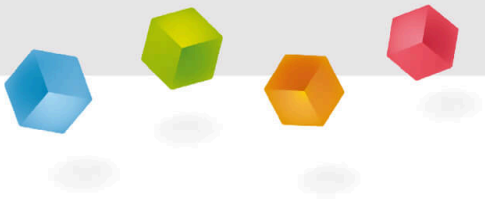

Setup and procedure 2

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Setup 2.1.1

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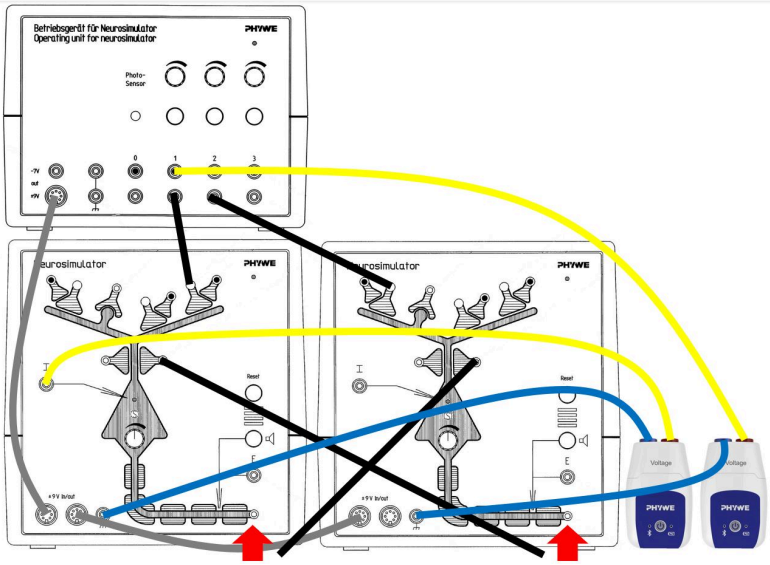

1. Lateral inhibition

- The experiment is set up as shown in the figure on the left.
- Leave two cables unplugged (red arrows).

Setup 2.1.2

PHYWE

- Neurosimulator 1: Rotary knob firing threshold: 0%
- Neurosimulator 2: Rotary knob firing threshold: 0%
- Power supply: Rotary knob stimulus intensity 1: 100%
- Power supply: Rotary knob stimulus intensity 2: 100%

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Procedure 2.1.1

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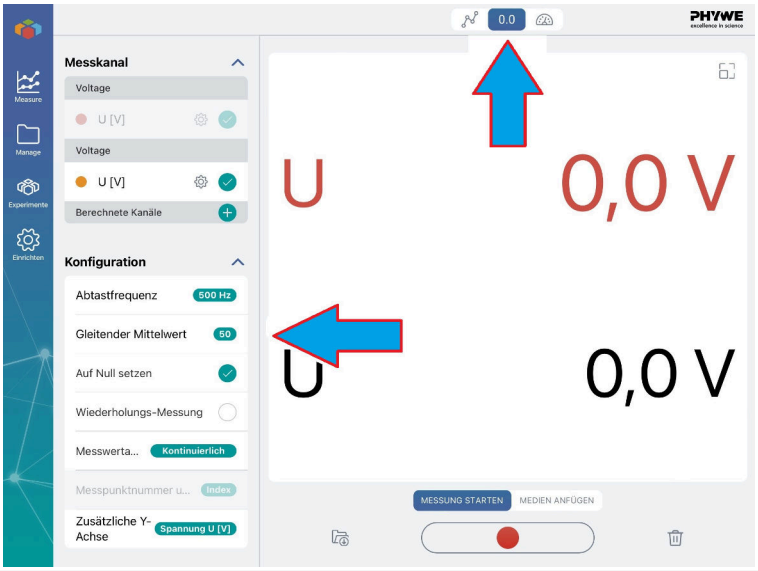


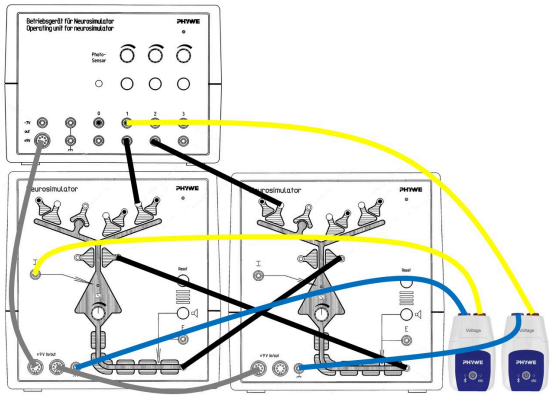
In order to get comparable results on both measuring channels, the two voltage sensors must be calibrated:

- Disconnect the circuit to the two voltage sensors.
- Switch display for calibration from graphic display to digital display.
- In the configuration, activate "Set to zero".
- Switch back to graphic display.

Procedure 2.1.2

PHYWE

- Start measurement.
- Press stimulation keys 1 and 2 for about 3 seconds. Wait until the voltage has reached the initial value.
- Plug the loose cables into the black sockets (see fig.).
- Press stimulation keys 1 and 2 again for approx. 3 seconds. Wait until the voltage has reached the initial value.
- Stop measurement as soon as the voltage has reached the initial value.
- Save and evaluate the result.



After plugging in the leads, the action potentials of the two nerve cells can be conducted to an inhibitory synapse of the other nerve cell.

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Setup 2.2

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2. Contrast enhancement

One of the two stimuli is reduced and the measurement is repeated. Otherwise, the experiment is set up as in step 1 of lateral inhibition.

- Neurosimulator 1 and Neurosimulator 2: Rotary knob firing threshold: 0% each
- Power supply: Rotary knob stimulus intensity 1: 100%
- Power supply: Rotary knob stimulus intensity 2: **66%**

Implementation 2.2

PHYWE

Repeat the steps of the measurement part 1 of lateral inhibition:

- Start measurement.
- Press stimulation keys 1 and 2 for about 3 seconds. Wait until the voltage has reached the initial value.
- Plug the loose cables into the black sockets (see fig.).
- Press stimulation keys 1 and 2 again for approx. 3 seconds. Wait until the voltage has reached the initial value.
- Stop measurement as soon as the voltage has reached the initial value.
- Save and evaluate the result.

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Evaluation 2

Result 2.1

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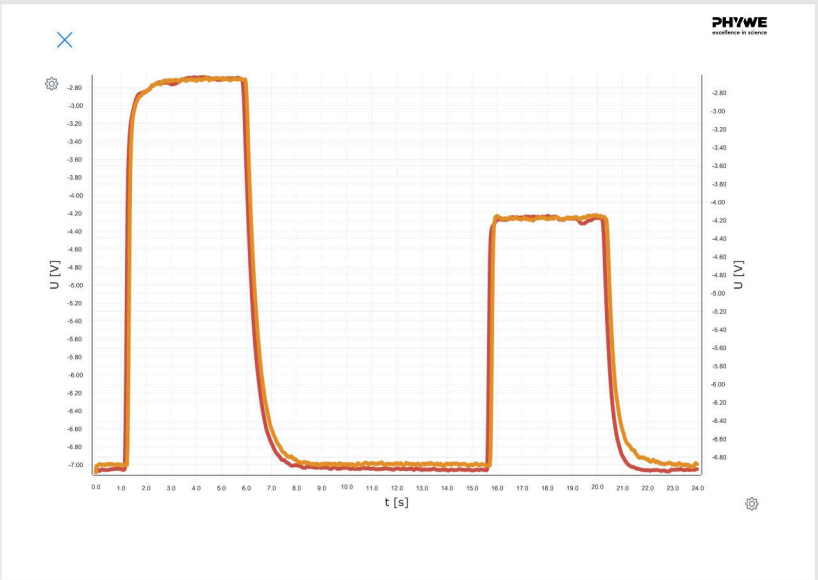
1. Lateral inhibition

The figure shows depolarisation without lateral inhibition (left) and with lateral inhibition (right). Before the second measurement, the two leads were connected.



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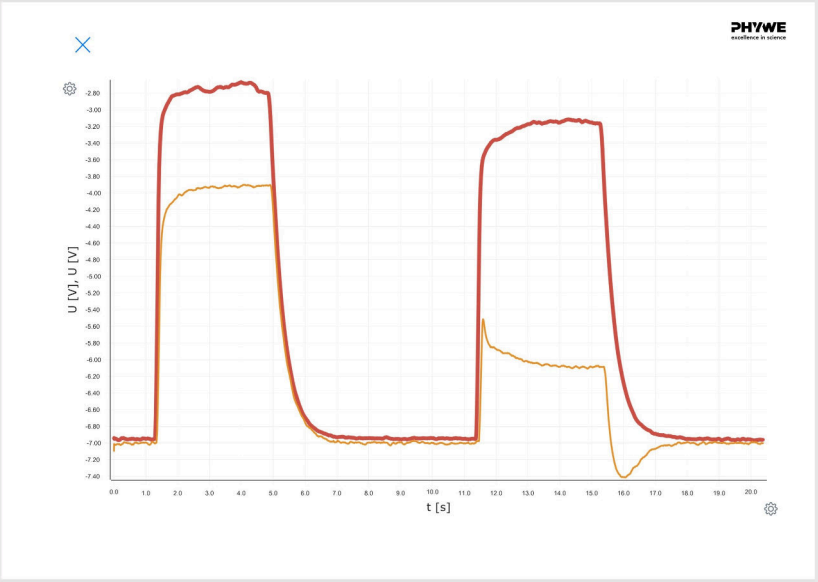
Result 2.2

PHYWE

2. Contrast enhancement

The diagram shows that depolarisation of the two nerve cells depends on the signal intensity (left). The difference is greater with lateral inhibition (right).



Theory 3

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Neuronal basics of classical conditioning

Pavlov's dog experiment is undoubtedly the best-known example of classical conditioning. The sound of a bell is associated with the smell of food and saliva is secreted in response. The perception of the smell of food and the resulting secretion of saliva is called an (innate) unconditioned reflex. The reaction to the sound of the bell, which is associated with the unconditioned reflex through learning, is called the conditioned reflex. In all classical conditioning experiments, it is imperative that the stimulus for the conditioned reflex be temporally prior to that for the unconditioned reflex. If this temporal sequence is reversed, conditioning is impossible. In the first experiment, the experiment is shown with the correct temporal sequence of conditioning. In the second experiment it is shown that the correct sequence is essential for the conditioned reflex to occur.

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Setup and procedure 3

Setup 3.1.1

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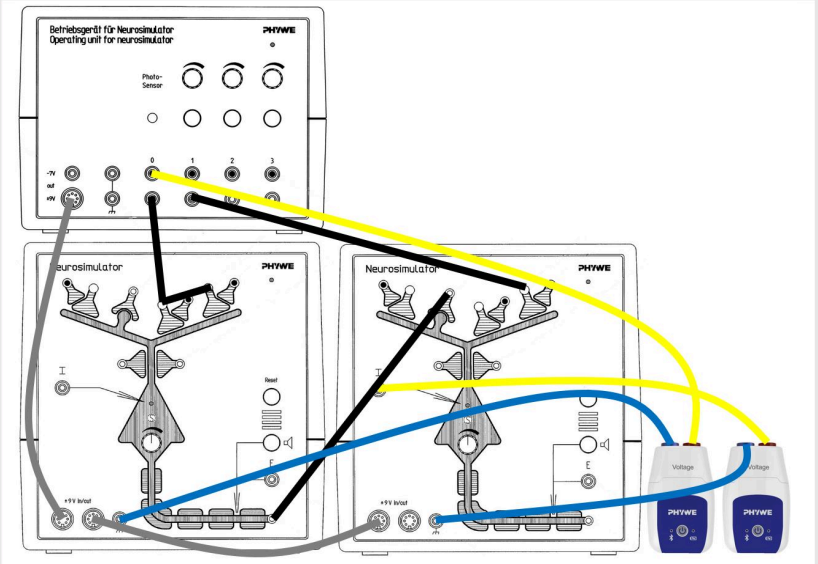
NOTE: In dim light, the sensor gives a continuous signal. In this case, the sensor should be illuminated with a torch.

1. Conditioned reflex

Set up the experiment as shown.



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Setup 3.1.2

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- Neurosimulator 1 and Neurosimulator 2: Rotary knob firing threshold: 0% each
- Power supply: Rotary knob stimulus intensity 1: 100%
- NOTES: The voltage should reach the output value (approx. -7 V) between each keystroke, covering the photosensor or operating both elements at the same time. Also: It is possible that too much light gets through the fingers. In this case, therefore, use an object that does not transmit light and cover the photosensor with it.

Procedure 3.1.1

PHYWE

- Press the reset button on Neurosimulator 2 (to set the Hebbian synapse to default values).
- Start measurement.
- Cover the photo sensor three times for one second (activation of the Hebbian synapse).
- Press stimulus button 1 three times for about one second (activation of the excitatory synapse).
- Briefly cover the photo sensor (for 1/2 s) and then briefly press the stimulus button 1 (for 1/2 s) immediately afterwards.
- Wait until the voltage has reached the initial value. Repeat this procedure about twenty times (successive activation of the Hebbian and excitatory synapses).
- Cover the photosensor three times for about one second (activation of the Hebbian synapse).

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Procedure 3.1.2

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- Press the reset button on the neurosimulator 2 to unlearn the conditioned reflex.
- Cover the photosensor three times for about one second (activation of the Hebbian synapse).
- Stop measurement as soon as the voltage has reached the initial value.
- Save and evaluate results.

Procedure 3.2.1

PHYWE

2. Reversed stimulus sequence

Repeat the previous experiment on the conditioned reflex, but this time press the stimulus button first and only then cover the photosensor.

NOTE: Between each button press, covering the photosensor or acting on both elements at the same time, the voltage should reach the output value (approx. -7 V).

Start measurement and perform almost the same actions as before:

- Cover the photo sensor three times for about one second (activation of the Hebbian synapse).
- Press stimulus button 1 three times for about one second (activation of the excitation synapse).
- First press the stimulus button briefly (for 1/2 s) and then immediately cover the photosensor briefly. Wait until the voltage has reached the initial value. Repeat this procedure about twenty times (successive activation of the excitatory and the Hebbian synapses).

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Procedure 3.2.2

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- Cover the photosensor three times for about one second (activation of the Hebbian synapse).
- Press the reset button on the Neurosimulator.
- Cover the light sensor three times for about one second (activation of the Hebbian synapse).
- Stop measurement as soon as the voltage has reached the initial value.
- Save and evaluate results.

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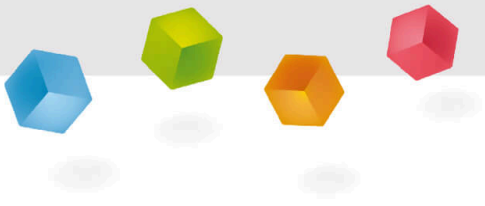

Evaluation 3

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Result 3.1.1

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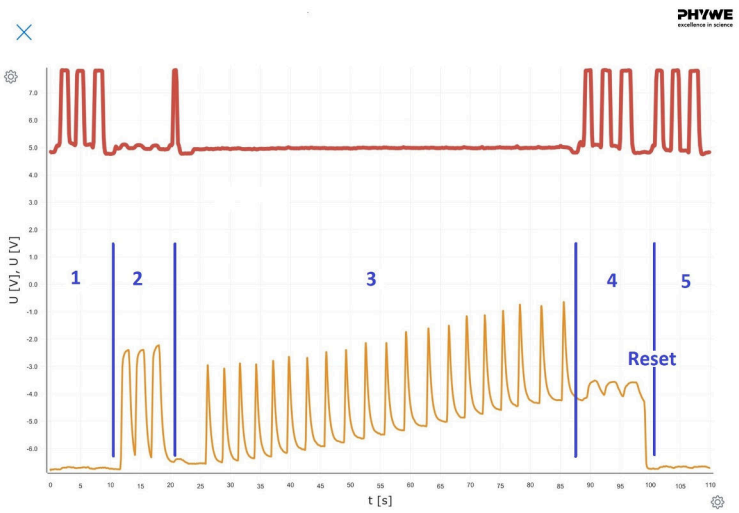
1. Conditioned reflex

Two Neurosimulators simulate the pair of interneuron and associative neuron.

In the experiment, the associative neuron is conditioned to increase its membrane potential (depolarisation) without the involvement of the interneuron.



Result 3.1.2

PHYWE

Explanation:

1. Activation of the Hebbian synapse before conditioning. The neutral stimulus (bell) does not produce a specific response.

2. Activation of the excitatory synapse before conditioning. The unconditioned stimulus (food) produces a **unconditioned response** (salivation = an unlearned reflex reaction).

3. Successive activation of the Hebbian and excitatory synapses during conditioning (Hebbian synapse first). The neutral stimulus (bell) is paired with an unconditioned stimulus (food). The unconditioned stimulus (food) produces an unconditioned response (salivation). The neutral stimulus (bell) becomes a **conditioned** stimulus.

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Result 3.1.3

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4. Activation of the Hebbian synapse after learning / after conditioning (**conditioned reflex**). The conditioned stimulus (bell) produces a conditioned response (salivation). The conditioned response is similar to the unconditioned response.

5. Activation of the Hebbian synapse after the **Unlearning** of the conditioned reflex (reset button).

NOTE: In dim light, the result may look different from that shown in the figure, because the Hebbian synapse is then falsely active all the time. The condition leads to a continuous excitation of the membrane potential. In this case, use the experiment with a torch.

Result 3.2

PHYWE

2. Reversed stimulus sequence

A reversed stimulus sequence does not lead to a conditioned reflex. In this case, no activation of the Hebbian synapse occurs. Instead, the EPSP in step 4 of the measurement is at the same level as in step 5 after the reset.

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