

GRADED POTENTIAL

Authored by
mohammad looti

October 11, 2025

RECOMMENDED CITATION

mohammad looti (2025). *GRADED POTENTIAL*. PSYCHOLOGICAL SCALES. Retrieved from <https://scales.arabpsychology.com/?p=43295>

GRADED POTENTIAL

Primary Disciplinary Field(s): Neuroscience, Physiology, Neurobiology

1. Core Definition

A **graded potential** is a transient, localized fluctuation in the electrical membrane potential of an excitable cell, such as a neuron or muscle cell, that is directly proportional to the intensity of the stimulus that evoked it. Unlike the action potential, which is an all-or-none phenomenon used for long-distance signaling, graded potentials serve as short-distance signals, playing a critical role in the integration of information within the dendrites and the cell body (soma). The defining characteristic of a graded potential is its **decremental conduction**, meaning the magnitude of the potential declines exponentially as it spreads passively away from its point of origin. This decay is a consequence of current leakage through the cell membrane and internal resistance, confirming that a graded potential is "not propagated" actively but passively diffuses, ensuring that its influence is highly localized.

These potentials are essential precursors to action potentials. They represent the initial electrical responses of the neuron to sensory input or synaptic communication. Because their amplitude is variable--they are "graded"--they allow the neuron to encode the strength of the incoming signal, translating varying stimulus intensities into varying voltage changes. Only when the summation of multiple graded potentials reaches a specific threshold at the axon hillock can a full, regenerative action potential be initiated for transmission along the axon.

2. Biophysical Mechanisms of Generation

Graded potentials are typically initiated by the opening or closing of specific types of ion channels that are not voltage-gated. The channels involved are primarily located in the receptor regions or postsynaptic membranes of the cell, such as the dendrites and soma. The most common mechanisms include the activation of **ligand-gated ion channels** and **mechanically gated ion channels**.

When a neurotransmitter binds to a ligand-gated receptor, it causes a conformational change that opens the channel pore, allowing specific ions--such as Na^+ , K^+ , or Cl^- --to flow across the membrane. The direction of this ionic flux determines the nature of the graded potential. For instance, the influx of positively charged sodium ions (Na^+) leads to depolarization, making the inside of the cell less negative and resulting in an **Excitatory Postsynaptic Potential (EPSP)**. Conversely, the influx of negatively charged chloride ions (Cl^-) or the efflux of positive potassium ions (K^+) leads to hyperpolarization or stabilization of the membrane potential, producing an **Inhibitory Postsynaptic Potential (IPSP)**. The duration of the graded potential is primarily

dictated by how long the stimulus is present and the mechanisms responsible for the inactivation or removal of the stimulus, such as the enzymatic breakdown or reuptake of neurotransmitters.

3. Key Characteristics and Properties

The operational features of graded potentials necessitate their classification as localized, integrative signals, fundamentally different from the regenerative signals of the axon. These characteristics are critical for the computational capacity of the neuron:

Graded Amplitude: The magnitude of the potential change is highly variable. A weak stimulus opens a small number of ion channels, generating a small potential. A strong stimulus opens many channels, generating a large potential. This contrasts sharply with the fixed amplitude of the all-or-none action potential.

Decremental Conduction: Graded potentials spread passively through local current flow across the membrane. As described by **cable theory**, this passive spread results in an exponential decline of the voltage change over distance from the source. The farther the potential must travel to reach the trigger zone (axon hillock), the weaker its influence will be, often failing to reach the required threshold.

Summation: Graded potentials are additive. This crucial property, known as summation, allows a neuron to integrate multiple inputs arriving simultaneously or in rapid succession. **Temporal summation** occurs when successive potentials, originating from the same site, overlap in time before they can completely decay. **Spatial summation** occurs when multiple potentials, arriving from different synaptic locations across the dendritic tree and soma, converge and combine their effects at the trigger zone.

Lack of Refractory Period: Unlike action potentials, graded potentials do not involve voltage-gated sodium channels and therefore lack a refractory period. This permits continuous, rapid summation of input signals, essential for rapid integration.

4. Types of Graded Potentials

Graded potentials are categorized based on their origin and function within the nervous system. The source material explicitly identifies several types:

Postsynaptic Potentials (PSPs): These are voltage changes occurring in the postsynaptic neuron after being activated by a neurotransmitter. They are the most common form of graded potential in the central nervous system. PSPs are critical for synaptic communication and are classified as either EPSPs (depolarizing, excitatory) or IPSPs (hyperpolarizing, inhibitory).

Receptor Potentials (Generator Potentials): These potentials are generated in sensory receptor cells in response to external stimuli (e.g., sound waves, pressure, light, chemical changes). The magnitude of the receptor potential directly encodes the intensity of the sensory input. In

specialized receptor neurons, if the receptor potential reaches threshold, it directly initiates action potentials that travel toward the central nervous system.

End-Plate Potentials (EPPs): A specific type of large excitatory potential occurring at the neuromuscular junction, where the release of acetylcholine causes massive depolarization of the muscle fiber membrane. While typically large enough to trigger an action potential in the muscle cell, the size of the EPP itself remains graded in response to the amount of acetylcholine released from the motor neuron.

Subthreshold Potentials: This is a descriptive term for any graded depolarization--such as a weak EPSP or receptor potential--that fails to reach the critical voltage threshold necessary to open the voltage-gated channels at the axon hillock and initiate a full action potential. They contribute to the neuron's overall electrical state but do not result in propagated output.

5. The Integration Function and Neuronal Decision-Making

The central significance of graded potentials lies in their ability to facilitate complex **neuronal integration**. A typical central neuron may receive thousands of synaptic inputs from converging pathways. These inputs arrive simultaneously as a mix of EPSPs and IPSPs across the vast surface area of the dendrites and soma. The neuron must then perform an ongoing algebraic summation of these inputs.

Because of their decremental nature, inputs arriving at distal dendritic branches have less influence on the trigger zone than inputs arriving near the soma or the axon hillock. Furthermore, inhibitory inputs (IPSPs) actively cancel out or subtract from the excitatory inputs (EPSPs). This complex spatial and temporal balancing act ensures that the neuron does not fire indiscriminately in response to minor stimulation. The decision to generate a rapid, long-distance signal (the action potential) is thus based entirely on the net sum of all incoming graded potentials reaching the axon hillock at any given moment. This integrative filtering mechanism provides the nervous system with the computational complexity required for nuanced processing.

6. Comparison with Action Potentials

Understanding graded potentials requires a clear delineation from action potentials, which serve distinct yet interconnected functions in neural communication:

Ion Channels Utilized: Graded potentials primarily rely on **ligand-gated** or **mechanically gated channels**. Action potentials rely exclusively on **voltage-gated channels**, particularly voltage-gated Na⁺ and K⁺ channels, which provide the positive feedback necessary for regeneration.

Propagation: Graded potentials are passively conducted and **decremental** (amplitude decays over distance). Action potentials are actively propagated (regenerated) and **non-decremental** (amplitude remains constant over long distances).

Amplitude and Stimulus Relation: Graded potentials have a **variable amplitude**, directly proportional to stimulus intensity. Action potentials follow the **all-or-none principle**; their amplitude is fixed once threshold is reached.

Polarity: Graded potentials can be **depolarizing (excitatory)** or **hyperpolarizing (inhibitory)**. Action potentials are always a sequence of depolarization followed by repolarization.

Function: Graded potentials function as **integrative, short-distance signals** that determine whether a message should be sent. Action potentials function as **output, long-distance signals** for transmitting information rapidly down the axon.

7. Clinical and Pharmacological Significance

The mechanisms governing graded potentials are major targets for pharmacological intervention and are implicated in numerous neurological pathologies. Drugs designed to treat disorders such as anxiety, depression, epilepsy, and pain often function by modulating the amplitude and duration of postsynaptic potentials.

For example, selective serotonin reuptake inhibitors (SSRIs) prolong the presence of serotonin in the synaptic cleft, thereby extending the duration and potential magnitude of the resulting postsynaptic potential in the target neuron. Furthermore, many general anesthetics act by enhancing inhibitory graded potentials (IPSPs), often by potentiating the action of GABA, thus hyperpolarizing neurons and reducing the likelihood of action potential generation throughout the central nervous system. Conversely, toxins that block the enzymatic breakdown of neurotransmitters, such as those implicated in tetanus, can excessively amplify EPSPs, leading to uncontrolled excitation and muscle spasms. A precise understanding of how synaptic inputs summate and decay--the core functions of the graded potential--is foundational to modern clinical neuropharmacology.

Further Reading

[Graded potential - Wikipedia](#)

[Synaptic Potentials and the Initiation of Action Potentials - NCBI Bookshelf](#)

[Graded Potential - ScienceDirect Topics](#)