GALVANIC SKIN RESPONSE (GSR)

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Primary Disciplinary Field(s): Psychophysiology, Experimental Psychology, Affective Neuroscience, Biomedical Engineering

1. Core Definition

The **Galvanic Skin Response (GSR)**, frequently referred to in academic literature as Electrodermal Activity (EDA) or Skin Conductance (SC), is a psychophysiological measure that quantifies changes in the electrical properties of the skin. These alterations are directly linked to the activity of the eccrine sweat glands, which are primarily innervated by the **sympathetic branch** of the autonomic nervous system. When an individual experiences cognitive effort, emotional stimulation, or environmental stress, the sympathetic outflow increases, leading to enhanced secretion of sweat. Since sweat contains electrolytes, this rise in moisture effectively lowers the skin's electrical resistance and, conversely, increases its electrical conductance. GSR, therefore, serves as a highly sensitive and non-invasive index of internal emotional and attentional arousal, reflecting the body's involuntary engagement with internal or external stimuli. This response can be elicited by a wide array of triggers, ranging from profound anxiety to states of high pleasure, confirming that the change is related to arousal intensity rather than emotional valence alone.

The measurement of GSR is most effective in areas of the body where eccrine sweat glands are densely populated and where hair growth is minimal, such as the palms of the hands (palmar conductance) and the soles of the feet (plantar conductance). These areas are particularly sensitive because the primary function of eccrine glands in these regions is related to emotional regulation and grip enhancement, rather than purely thermoregulation. The resulting electrical signal is rapid and transient, providing researchers with real-time data on momentary physiological fluctuations corresponding to specific stimuli presentation or cognitive events.

2. Etymology and Historical Development

The foundational discoveries leading to the study of electrodermal activity date back to the late 19th century. In 1888, the French physician **Charles Féré** documented that the electrical resistance of human skin fluctuated markedly in response to various forms of sensory and emotional stimulation. He noted that these changes were involuntary and reflex-like, initially terming the phenomenon the "psycho-electric reflex." Simultaneously, the Russian physiologist **Ivan Tarchanoff** observed a related phenomenon where a potential difference (voltage) could be measured between two distinct points on the skin surface, independent of an external power source--a measure known as the Skin Potential Response (SPR) or Tarchanoff effect.

These early observations paved the way for the clinical application of the psychogalvanic reflex

(PGR) in the early 20th century. Notably, **Carl Gustav Jung** integrated GSR measurement into his word association tests, using the magnitude of the response to identify emotionally salient or repressed psychological complexes in his patients. This pioneering work established GSR as a crucial indicator of emotional activation, contributing significantly to the development of modern psychophysiology as a dedicated field of study. Over time, advancements in electronic measurement and standardized methodology led to the preferred terminology of Electrodermal Activity (EDA) and Skin Conductance (SC) to better reflect the specific electrical property being quantified.

3. Physiological Mechanism

The precise mechanism underlying GSR is rooted in the neuroanatomy of the eccrine sweat gland system. Eccrine glands, unlike the thermoregulatory apocrine glands, are highly responsive to psychological states. They are innervated by post-ganglionic cholinergic fibers of the **sympathetic nervous system**. When an acute stressor or an emotionally engaging stimulus is processed, signals originating in the limbic system--particularly the amygdala--are relayed through the hypothalamus to the sympathetic chain. This cascade results in the rapid release of acetylcholine at the gland site.

The secretion of sweat onto the skin surface and into the glandular ducts significantly increases the concentration of ions (electrolytes) present at the stratum corneum layer. This electrolyte-rich solution enhances the ability of the skin surface to conduct electricity. Essentially, the sweat glands and their associated ducts act as variable resistors embedded in the skin tissue. An increase in sympathetic activity reduces the total electrical impedance of the skin, allowing current to flow more easily between the measurement electrodes. Since this activity is entirely involuntary and reflects deep-seated autonomic processing, GSR provides a unique window into underlying emotional states that may not be apparent through conscious self-report.

4. Measurement and Instrumentation

GSR is typically measured using non-polarizing silver/silver chloride (Ag/AgCl) electrodes placed across an area of high eccrine gland density. While the older method involved measuring resistance (Ohms), contemporary psychophysiology almost exclusively focuses on measuring **conductance** (microSiemens, µS), which provides a more linear relationship with sweat gland activity. The total measured EDA signal is conceptually divided into two distinct components that reflect different temporal aspects of autonomic regulation:

Skin Conductance Level (SCL): This represents the tonic component of EDA. SCL is the baseline or slowly fluctuating measure of skin conductance over minutes or hours. It is thought to reflect generalized, ambient levels of sympathetic arousal, mood state, and thermoregulation. High

SCL is often associated with sustained stress, anxiety, or high cognitive load.

Skin Conductance Response (SCR): This is the phasic component, characterized by rapid, temporary increases in conductance that occur within seconds of a discrete external or internal stimulus (e.g., a sudden noise, an image, or a memory). The key metrics analyzed here include the amplitude (magnitude of the response), the latency (time from stimulus onset to response start), and the recovery half-time (the speed at which the conductance returns to baseline). The SCR is the primary indicator used to assess attention, orienting reflexes, and the intensity of immediate emotional reactions.

5. Applications in Research and Clinical Settings

The robust relationship between GSR and sympathetic arousal makes it a critical measure in diverse scientific and applied fields. In **affective neuroscience** and experimental psychology, GSR is vital for objectifying emotional responses, allowing researchers to study how the brain processes stimuli associated with fear, reward, novelty, and learned helplessness. For instance, in classical conditioning paradigms, the pairing of a neutral stimulus with an aversive one can be tracked by the increasing amplitude of the SCR to the previously neutral stimulus, demonstrating physiological learning.

Clinically, GSR is a cornerstone of **biofeedback therapy**, where patients are trained to consciously regulate their skin conductance levels. By visualizing their autonomic responses, individuals suffering from generalized anxiety disorder, phobias, or chronic stress can learn relaxation techniques that result in measurable decreases in sympathetic arousal. Furthermore, the measurement is historically relevant in forensic psychology as a core component of the traditional **polygraph** (lie detector), where significant SCRs are interpreted as potential indicators of stress or deception related to concealed information, although the scientific validity of the polygraph itself remains highly controversial. In modern research, GSR is increasingly integrated into wearable technology to monitor stress and engagement in real-world settings, including driver safety analysis and human-computer interaction studies.

6. Limitations and Methodological Debates

Despite its extensive use, GSR interpretation presents several methodological complexities. A fundamental limitation is the **lack of valence specificity**; a strong SCR indicates high arousal but does not distinguish between a positive response (e.g., excitement) and a negative response (e.g., fear). Researchers must rely on self-report measures, contextual information, or simultaneous measurement of other physiological markers (like heart rate or facial electromyography) to infer the emotional quality of the arousal.

Furthermore, GSR is highly susceptible to external and internal noise. Baseline skin conductance levels can fluctuate dramatically due to uncontrolled variables such as ambient temperature, humidity, hydration status, and even the subject's posture or movement. These factors can introduce artifacts that obscure the genuine response signal, requiring stringent experimental controls and advanced signal processing techniques to isolate the relevant phasic responses. Finally, debates persist regarding the standardization of electrode materials, placement protocols, and filtering methods, which can impact the comparability and replication of GSR findings across different laboratories and studies.

7. Further Reading

Electrodermal Activity (EDA) - Wikipedia
Society for Psychophysiological Research (SPR)
Galvanic Skin Response Overview - ScienceDirect