

# Foundations of Psychophysiology

Part 7: Electrodermal activity

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# Psychophysiology

## **Electrodermal activity (EDA)**

History

The human skin

Measuring EDA

Analysis of EDA

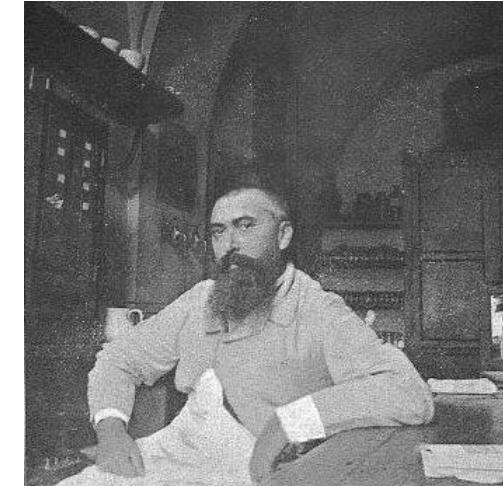
# Psychophysiology: Electrodermal activity

## History

In 1888, Charles Féré “attached two electrodes on the forearm, connected in series with a weak current and a galvanometer.”

He found deflections when the participant “was stimulated by a tuning fork, an odor, or a colored glass before his eyes.”

In 1890, Ivan Tarkhanov found similar results without a current.



# Psychophysiology: Electrodermal activity

## History

Both methods immediately generated interest, and were applied i.a. by Carl Jung in the early 1900s “to study emotional reactions of his patients to word associations”.

Féré had measured a sweat-induced change in *skin conductance*.

Tarkhanov had detected *skin potentials*.



# Psychophysiology: Electrodermal activity

## History

Other names for the same or similar effects:

- Galvanic skin response
- Electrodermal response
- Psychogalvanic reflex
- Sympathetic skin response
- ...

# Psychophysiology

## The human skin

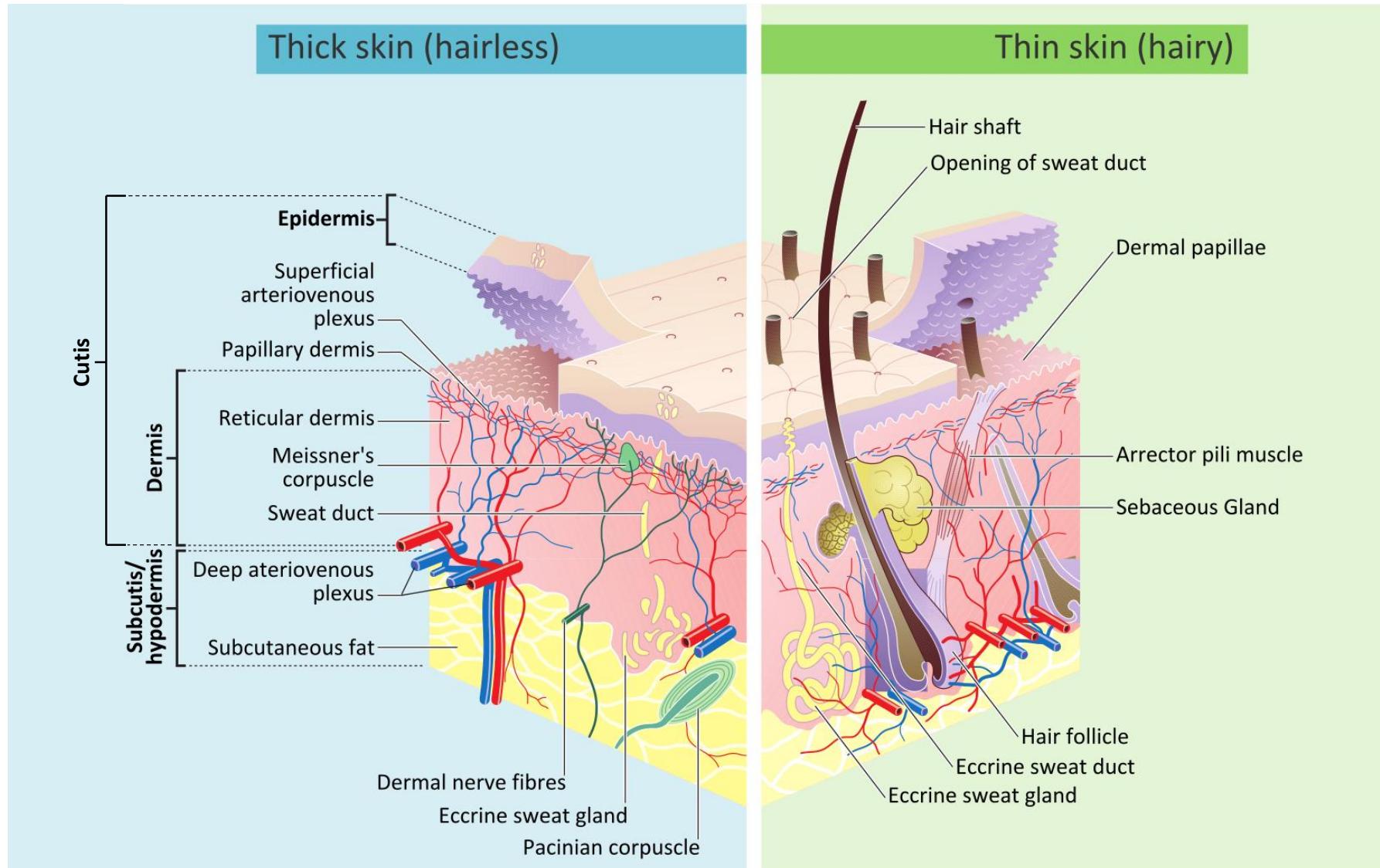
# Psychophysiology: Electrodermal activity: Skin

## Main functions

- Protection
  - Against the external environment
  - Against mechanical damage
  - Against pathogens
  - Against loss of water, nutrients ...
- Sensation
  - Temperature, pressure, vibration, injury ...
- Regulation
  - Blood vessel dilation and constriction
  - “Goose bumps”
  - Sweat glands

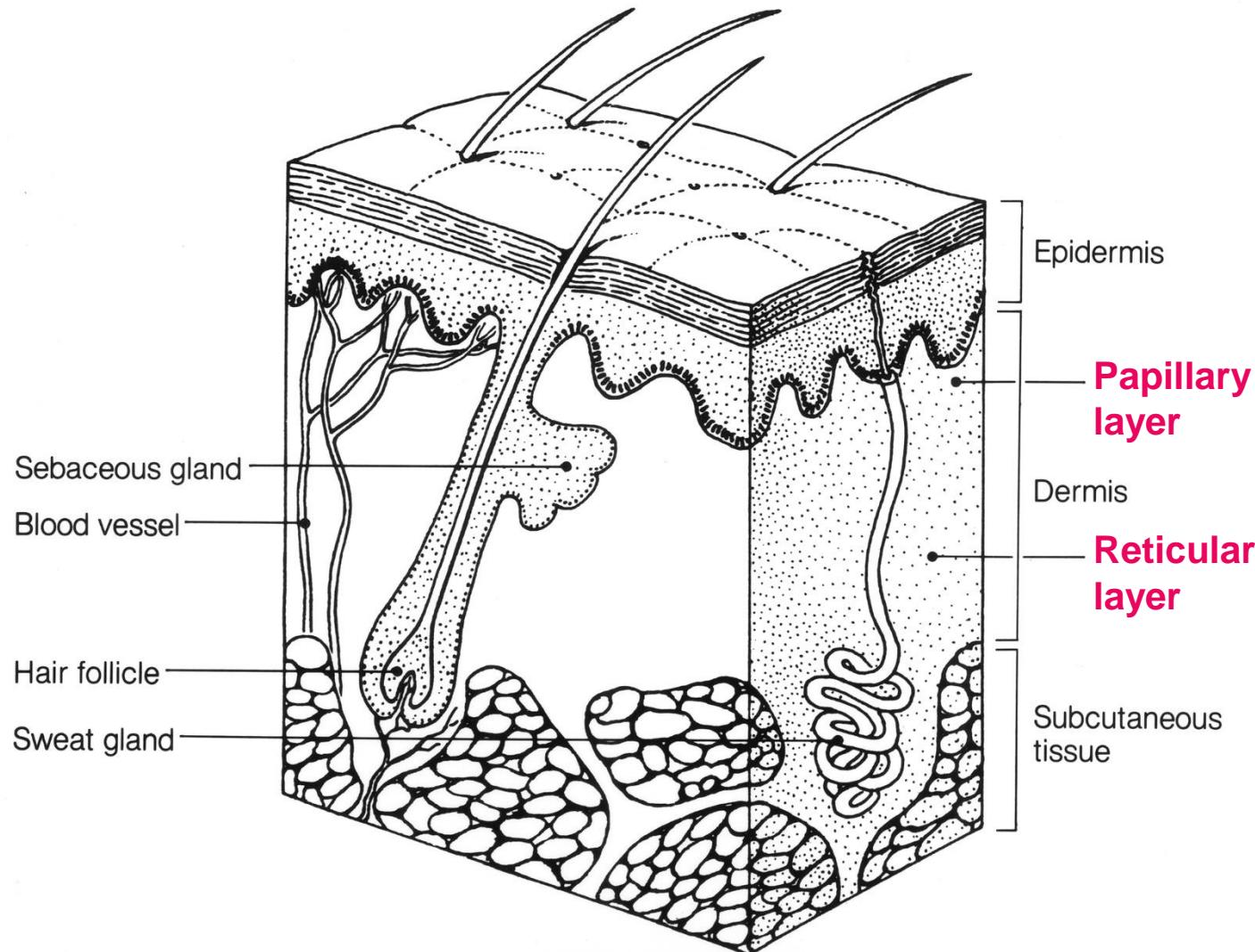
# Psychophysiology: Electrodermal activity: Skin

## Histology of the skin



# Psychophysiology: Electrodermal activity: Skin: Histology

## Layers of the dermis

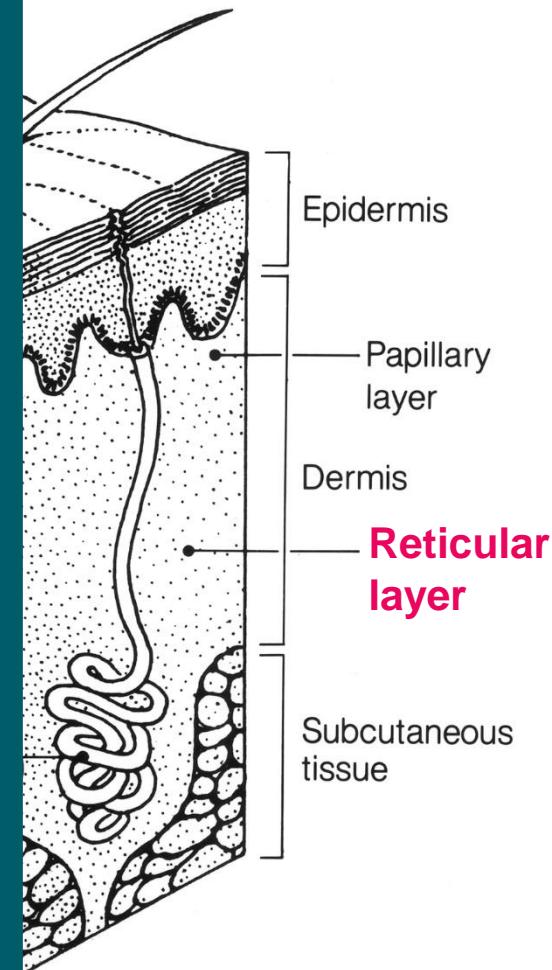


# Psychophysiology: Electrodermal activity: Skin: Histology

## Layers of the dermis

The *reticular layer* is the main part of the dermis, containing various structural fibers as well as blood vessels, glands, hair follicles, and sensory neurons.

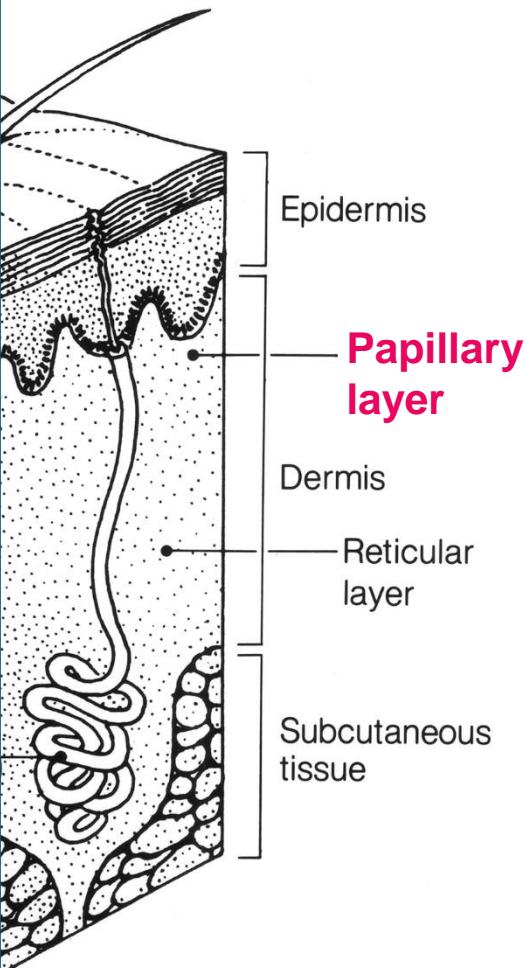
The *subcutaneous tissue* or *hypodermis* below is not technically considered to be part of the skin, but connects the skin to the body.



# Psychophysiology: Electrodermal activity: Skin: Histology

## Layers of the dermis

The *papillary layer* connects to the epidermal basal layer and is named for the *dermal papillae*.

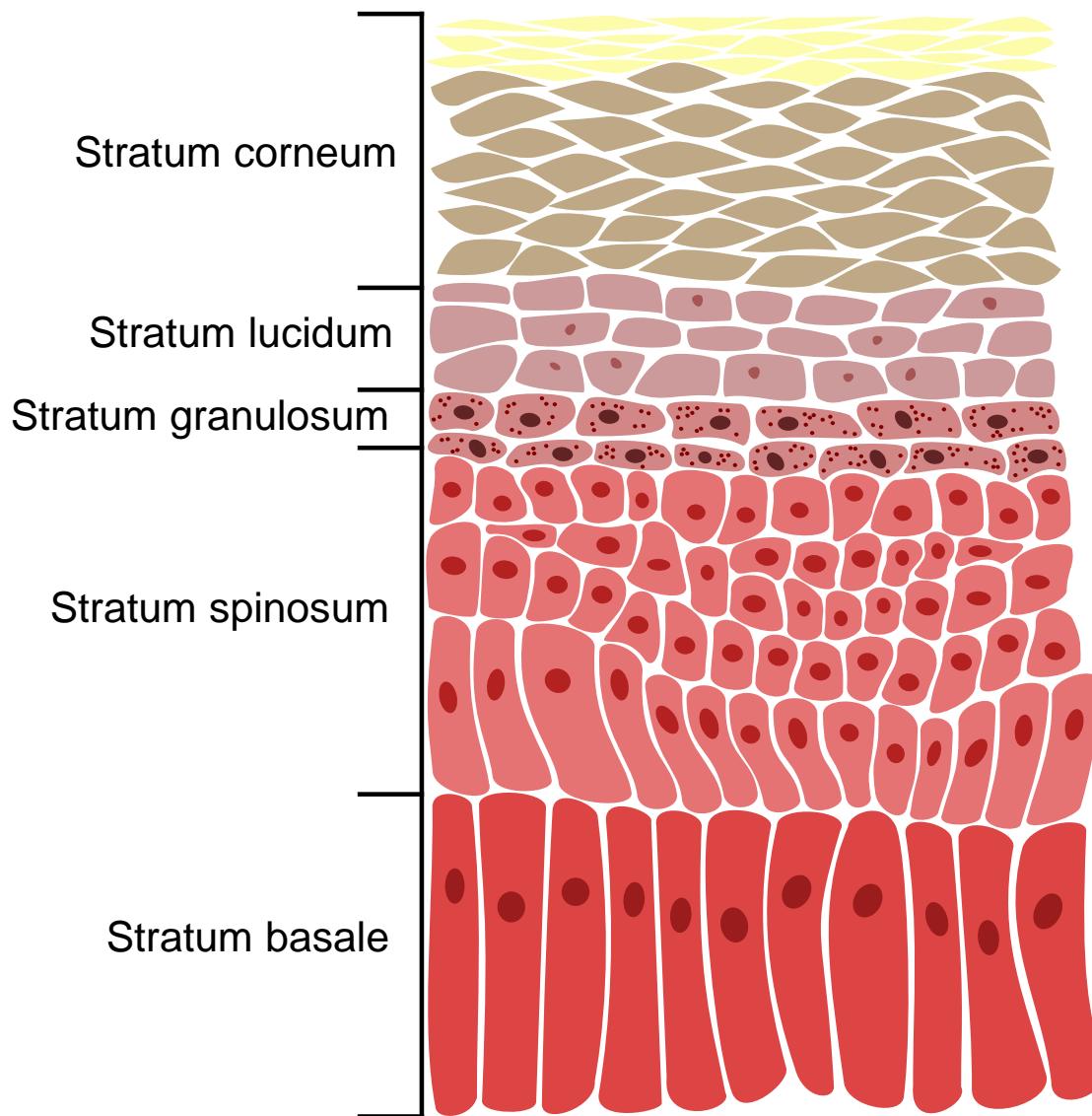


Dermal papillae are small extensions that project into the epidermis, improving the exchange of oxygen, nutrients, and waste products, as the epidermis has no blood vessels. They also strengthen the bond between dermis and epidermis.

They appear as ridges on the epidermis of thick skin, known as *fingerprints* on the fingertips.

# Psychophysiology: Electrodermal activity: Skin: Histology

## Layers of the epidermis



Epidermal cells are primarily *keratinocytes* producing *keratin* and other substances that protect the skin.

These cells are generated in the *stratum basale* and pushed upwards.

The outer *stratum corneum* consists of these dead cells, plus their secretions.

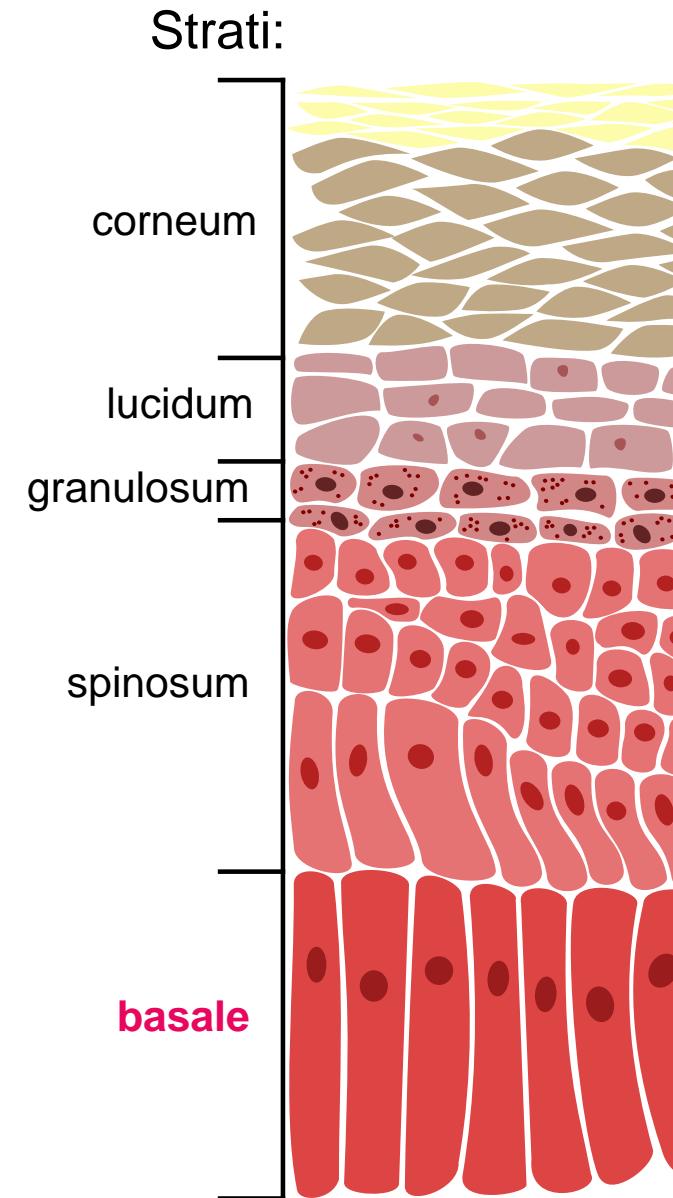
# Psychophysiology: Electrodermal activity: Skin: Histology

## Layers of the epidermis

The *stratum basale* contains a single layer of *basal cells* which serve as stem cells to create keratinocytes through mitosis, pushing the existing cells outwards.

It also contains sensory receptor cells for touch (*Merkel cells*), as well as *melanocytes*, creating melanin.

The stratum basale is connected to the lower *dermis*.

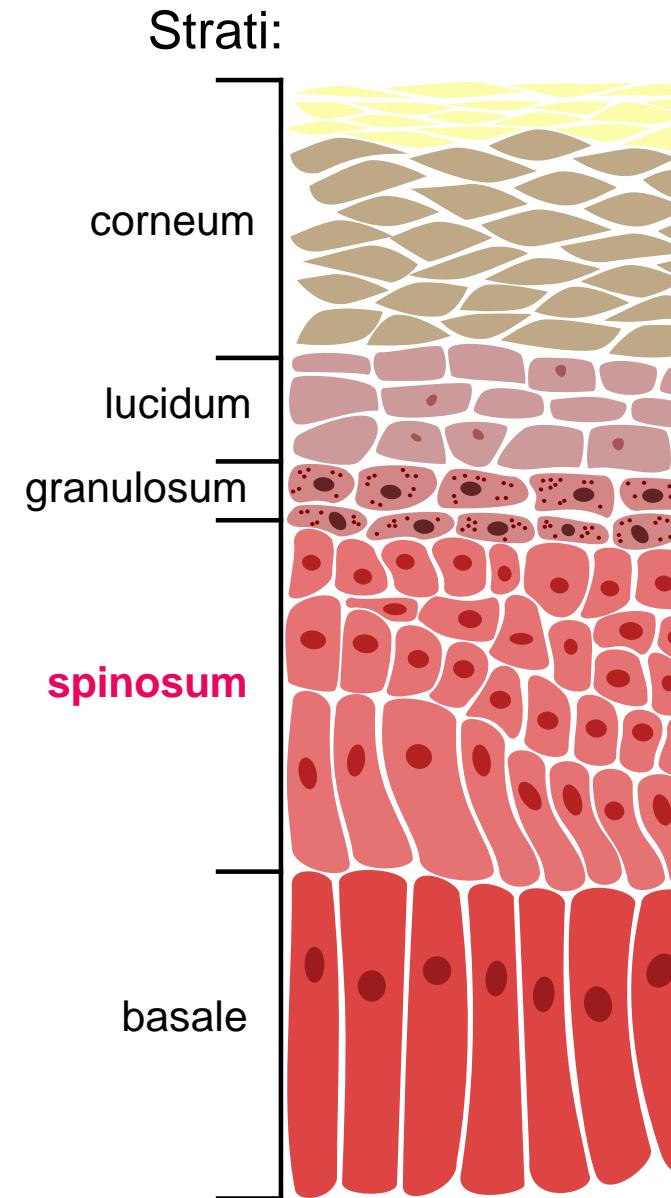


# Psychophysiology: Electrodermal activity: Skin: Histology

## Layers of the epidermis

The *stratum spinosum* consists of approximately 10 layers of young keratinocytes, providing water resistance.

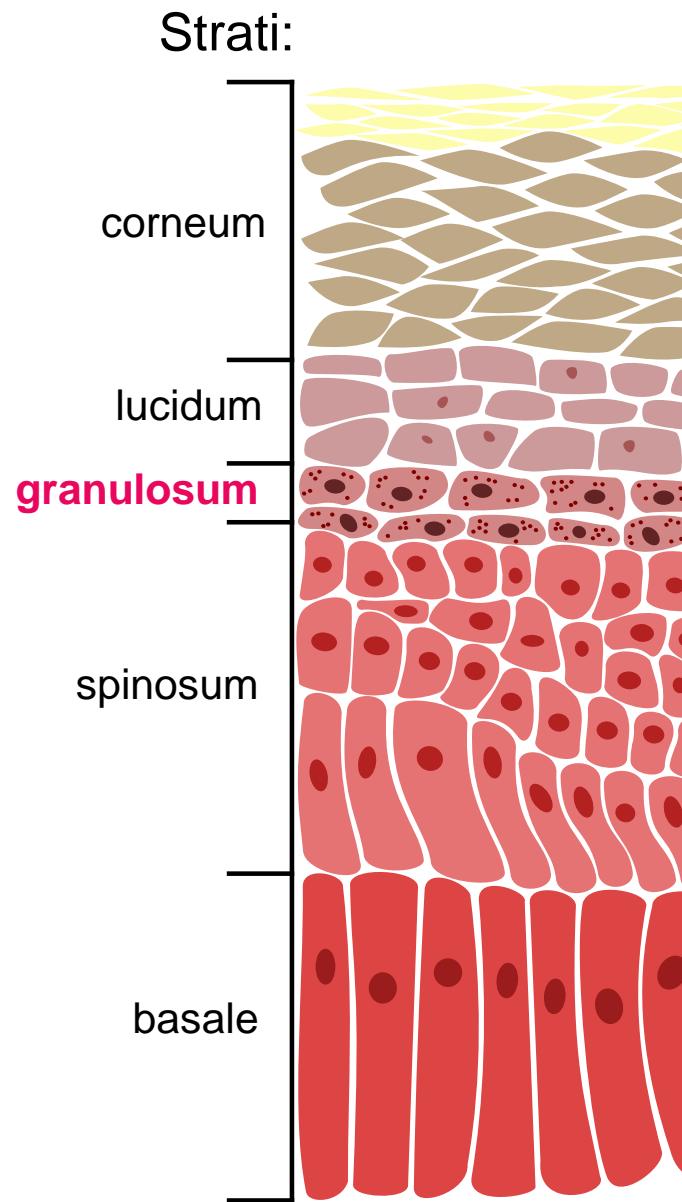
This layer also contains *Langerhans cells*, parts of the immune system that protect against bacteria and other foreign particles.



# Psychophysiology: Electrodermal activity: Skin: Histology

## Layers of the epidermis

In the *stratum granulosum*, 3 – 5 layers of keratinocytes create large amounts of keratin and other proteins, before dying.

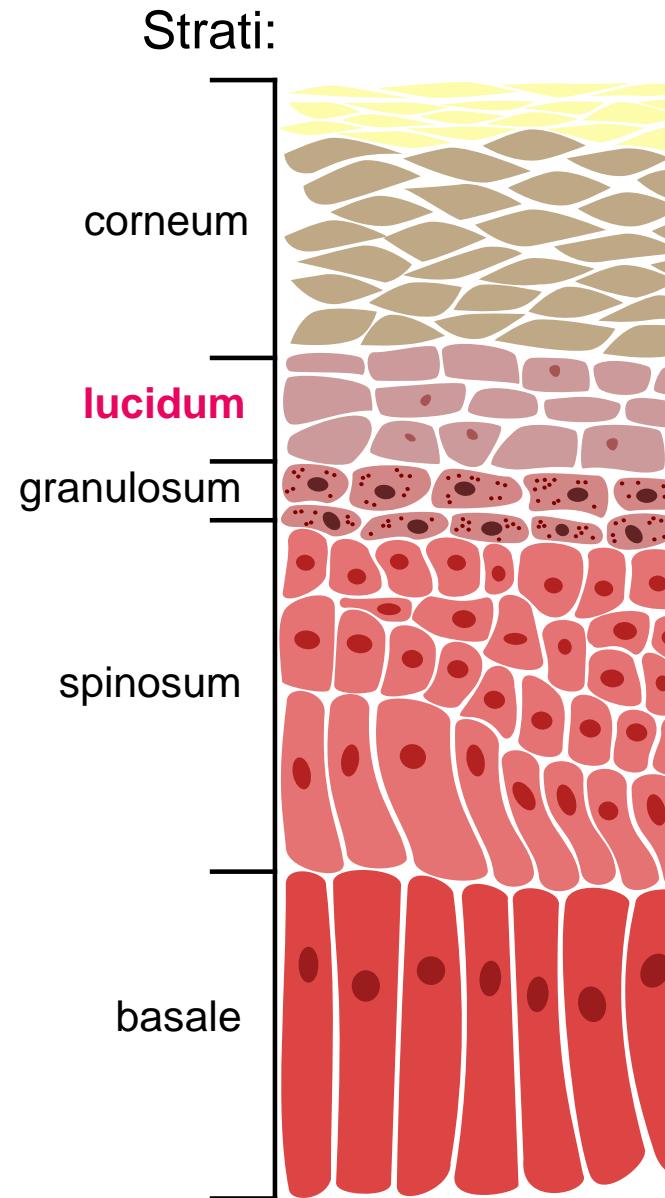


# Psychophysiology: Electrodermal activity: Skin: Histology

## Layers of the epidermis

This layer, the *stratum lucidum*, only exists in the sections of “thick skin” in the palms of the hand and the soles of the feet.

It consists of 3 – 5 layers of dead keratinocytes and a derivate protein, giving it a translucent appearance.



# Psychophysiology: Electrodermal activity: Skin: Histology

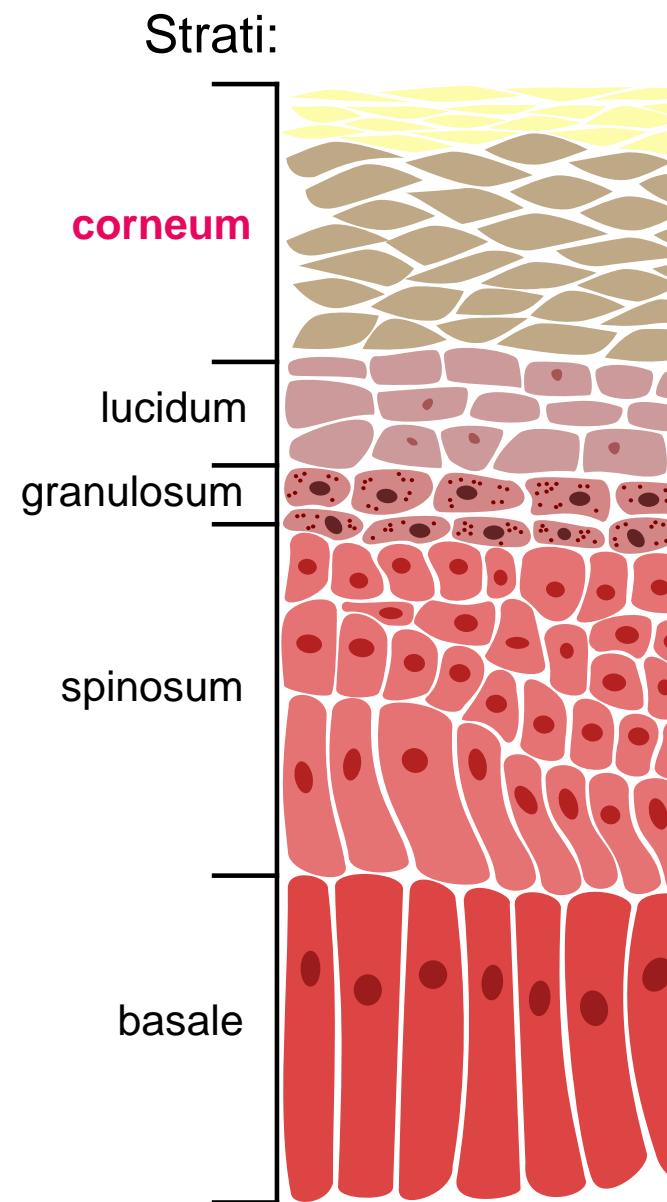
## Layers of the epidermis

The *stratum corneum* is the outermost layer of the skin.

With 10 – 30 layers of cells, it is thickest at the palms and soles.

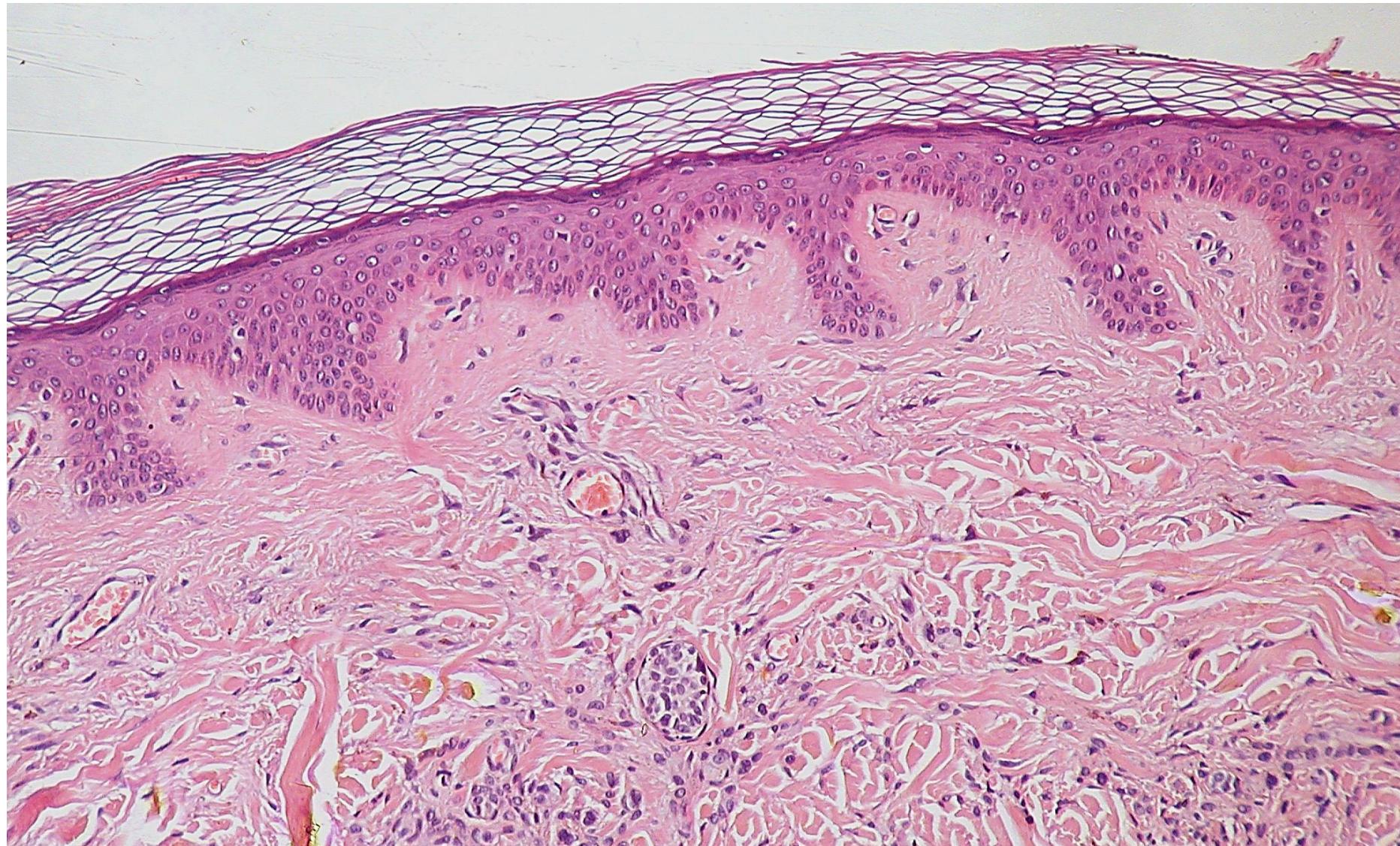
Consisting of dead, dry, keratinized cells, this layer serves as a physical barrier against external substances and mechanical influences.

This layer is shed by friction, and replaced with new cells from lower layers approximately every four weeks.



# Psychophysiology: Electrodermal activity: Skin: Histology

## Layers of the dermis



# Psychophysiology: Electrodermal activity: Skin: Histology

## Layers of the epidermis

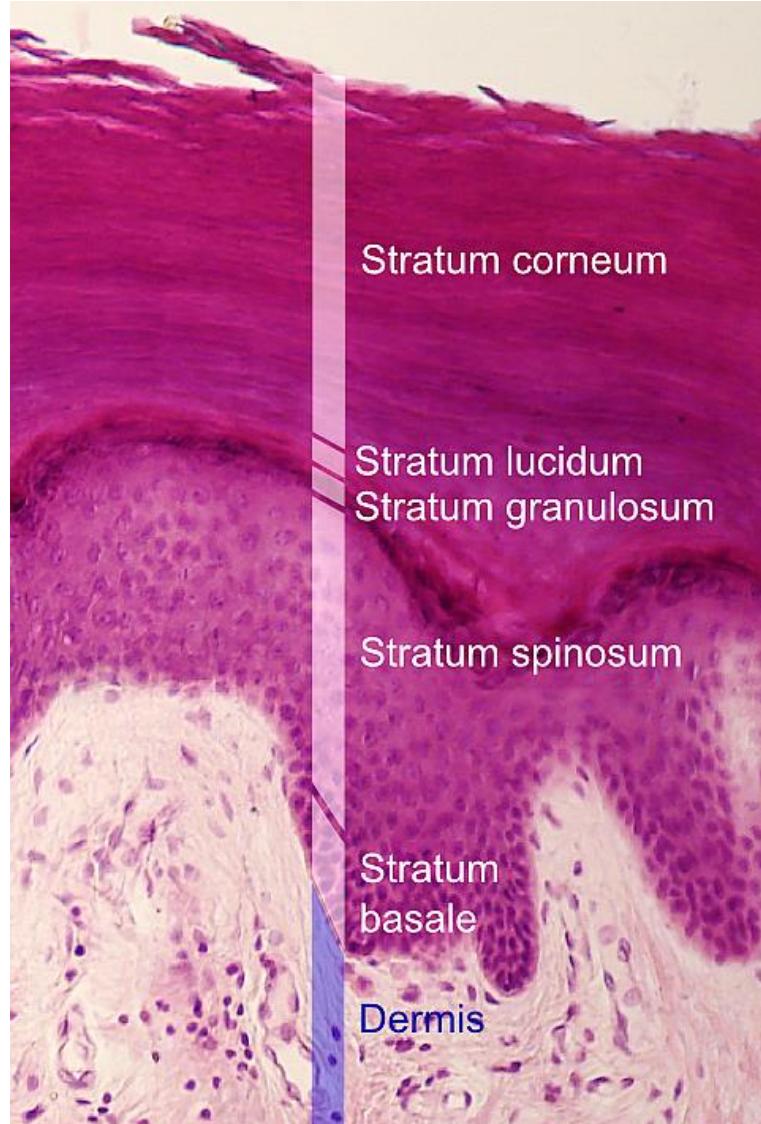


Figure “Epidermal layers” by Mikael Häggström / Wbenschmidt is licensed under CC BY-SA 3.0

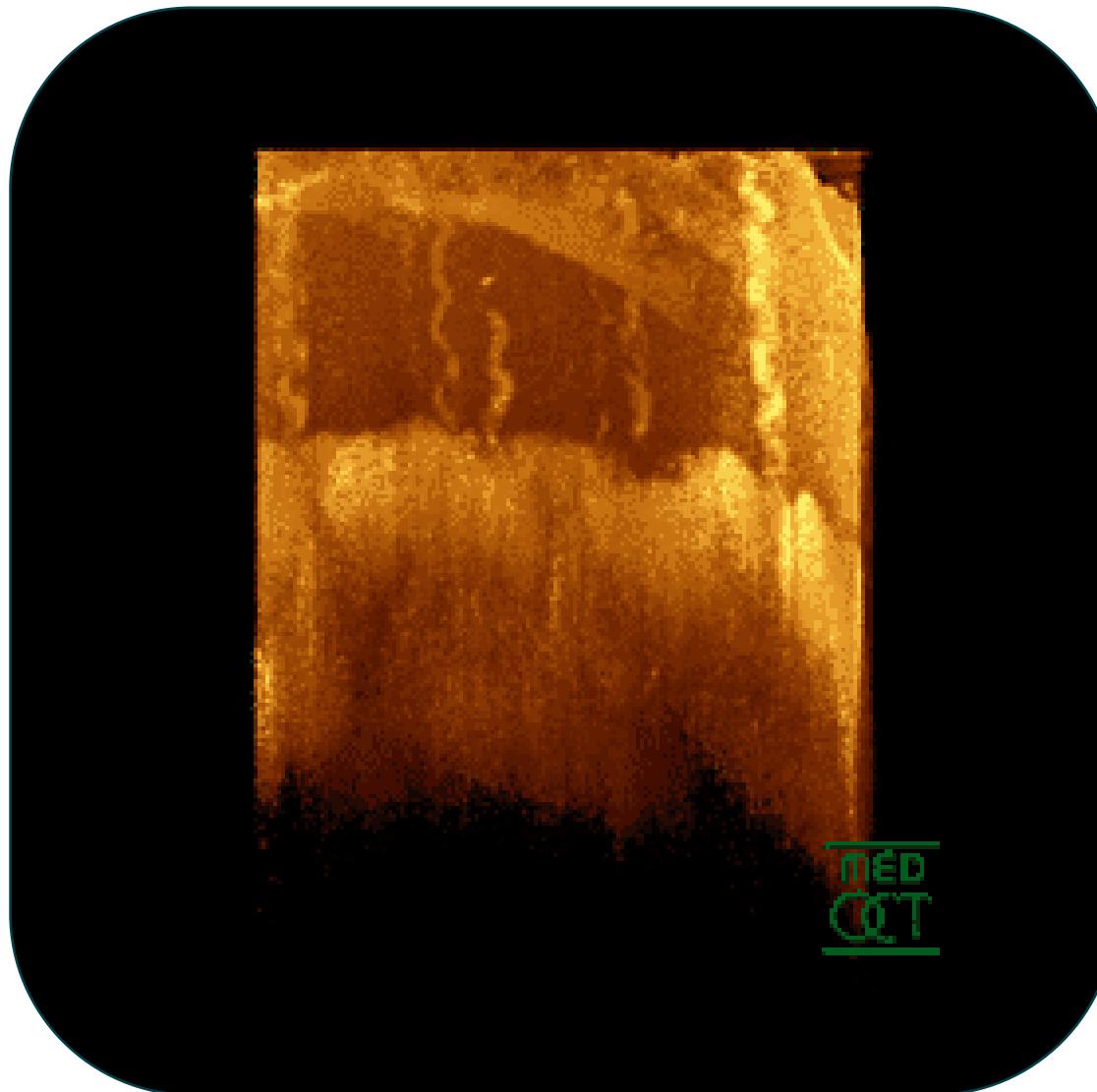
## Sweat glands

Sweat glands are a type of *exocrine* gland, secreting products through a duct onto an outer tissue layer, as opposed to *endocrine* glands, which secrete directly into the bloodstream.

- *Apocrine* sweat glands secrete relatively oily liquid containing proteins and fats. They are only found in specific regions (e.g. armpits, areola, anus, pubic), and begin working during puberty.
- *Eccrine* sweat glands secrete 99% clear H<sub>2</sub>O, and are present almost everywhere. An estimated 2 – 5 million glands are found at different densities, with ~2000/cm<sup>2</sup> at the palms and soles, down to ~100/cm<sup>2</sup> elsewhere.

# Psychophysiology: Electrodermal activity: Skin: Histology

## Sweat glands



# Psychophysiology: Electrodermal activity

## Skin conductance

Eccrine sweat glands are known to be the main factor in skin conductance, because:

- Skin conductance is strongest in areas with the highest density of eccrine sweat glands, even though the skin itself is thicker there.
- EDA responses are strongest in those same areas.
- No such responses are measured in people without eccrine sweat glands.
- The response can be eliminated by e.g. chemically blocking the signals responsible for gland activation.

# Psychophysiology: Electrodermal activity: Skin

## Eccrine sweat gland innervation

Eccrine sweat glands are exclusively under sympathetic control.

Electrodermal activity (EDA) appears to be a complex reaction, involving, aside from local skin processes, CNS systems related to (loco)motion, arousal, emotion, and motivation.

- Motor cortex, some basal ganglia → (loco)motion
- Reticular formation → arousal
- Limbic system → emotion (and thermoregulation)
- (Frontotemporal) cortex → motivation

# Psychophysiology: Electrodermal activity: Skin

## Eccrine sweat production

Sweating appears to not purely serve thermoregulation.

The eccrine glands in the hands and feet respond weakly to temperature, and more strongly to psychological stimuli.

Possible evolutionary advantages: sweat aids grasping, protects against injury, and lowers body temperature.

# Psychophysiology

## The human skin

The human skin consists of two layers, the outer epidermis, and the inner dermis.

It aids or enables protection, sensation, and regulation.

Eccrine sweat glands in the dermis are exclusively under sympathetic control, and respond to psychological stimuli.

# Psychophysiology: Electrodermal activity

## Measuring EDA

# Psychophysiology: Electrodermal activity: Measurement

## Conductance

We will focus on conductance, as potential recordings are less common, and the mechanism still not fully explained.

Conductivity  $C$  is the reciprocal of resistivity.

$$\text{Ohm's law: } R = \frac{V}{I} \quad \text{Therefore: } C = \frac{1}{R} = \frac{I}{V}$$

The conductivity unit *siemens* (S) is thus  $\Omega^{-1}$ , with electrical conductance additionally dependent on the surface of the electrode, finally using S/m as unit.

For EDA, the scale is usually in  $\mu\text{S}$ .

A traditional, non-SI unit that is otherwise equivalent to siemens is *mho*.

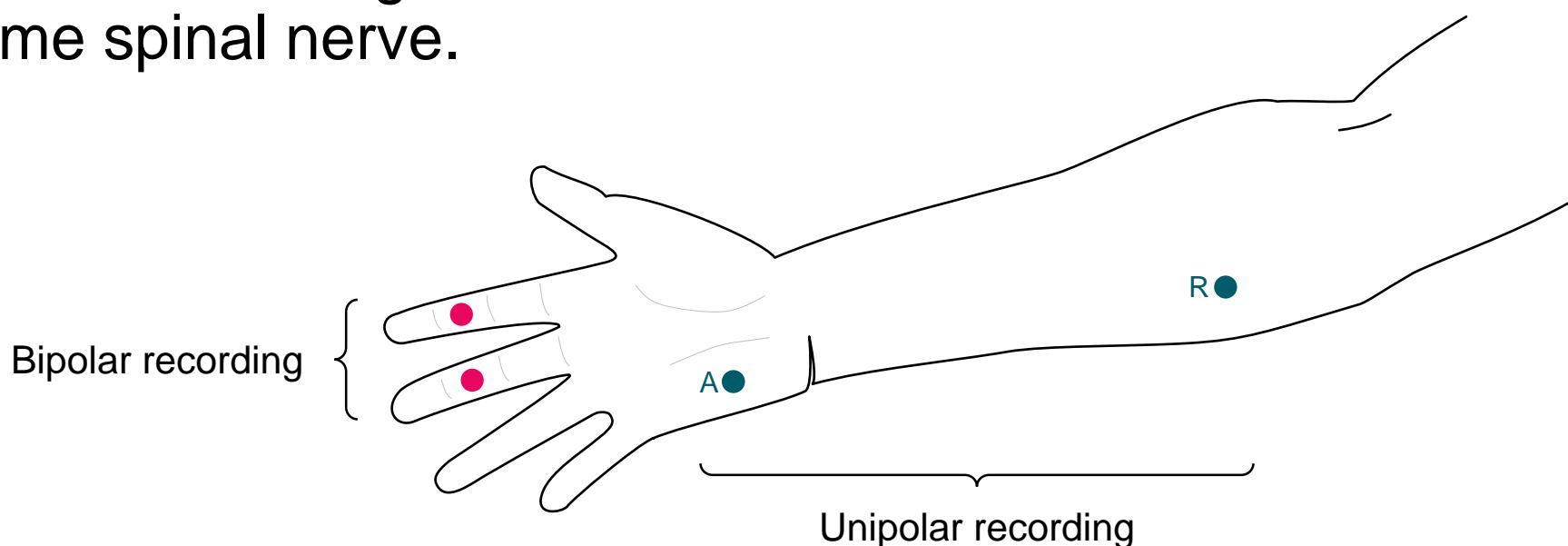
# Psychophysiology: Electrodermal activity: Measurement

## Electrode locations

For skin conductance a bipolar, and for skin potential recordings a unipolar recording is preferred.

The unipolar reference site should be made neutral, e.g. using a subdermal electrode.

Bipolar recordings sites should be innervated from the same spinal nerve.



# Psychophysiology: Electrodermal activity: Measurement

## Recording conductance

The non-dominant hand is often used as the corneum tends to be thinner.

This hand should be washed beforehand, but not with soap. Alcohol may be used instead.

Electrodes should be as big as practically feasible to increase signal quality. (For comparison and standardisation, measurements should be normalised with respect to this area.)

Avoid artificially increasing the area by “leaking” gel.

# Psychophysiology: Electrodermal activity: Measurement

## Artefacts

- Temperature, humidity
  - Should be held constant; participant may need to acclimatize
- Respiratory cycle, cardiac activity
  - May be recorded simultaneously
- Mechanical, electrical, or thermal stimulation of the skin near the electrodes
  - Results in activity that is hard to distinguish from psychologically relevant activity

# Psychophysiology: Electrodermal activity

## Analysis of EDA

# Psychophysiology: Electrodermal activity: Analysis

## Tonic vs phasic changes

In signal analysis, two types of activity are distinguished:

- slow, *tonic* changes of  $\sim 2 - 100 \mu\text{S}/\text{cm}^2$ , and
- faster, *phasic* changes of  $\sim 0.01 - 5 \mu\text{S}/\text{cm}^2$ .

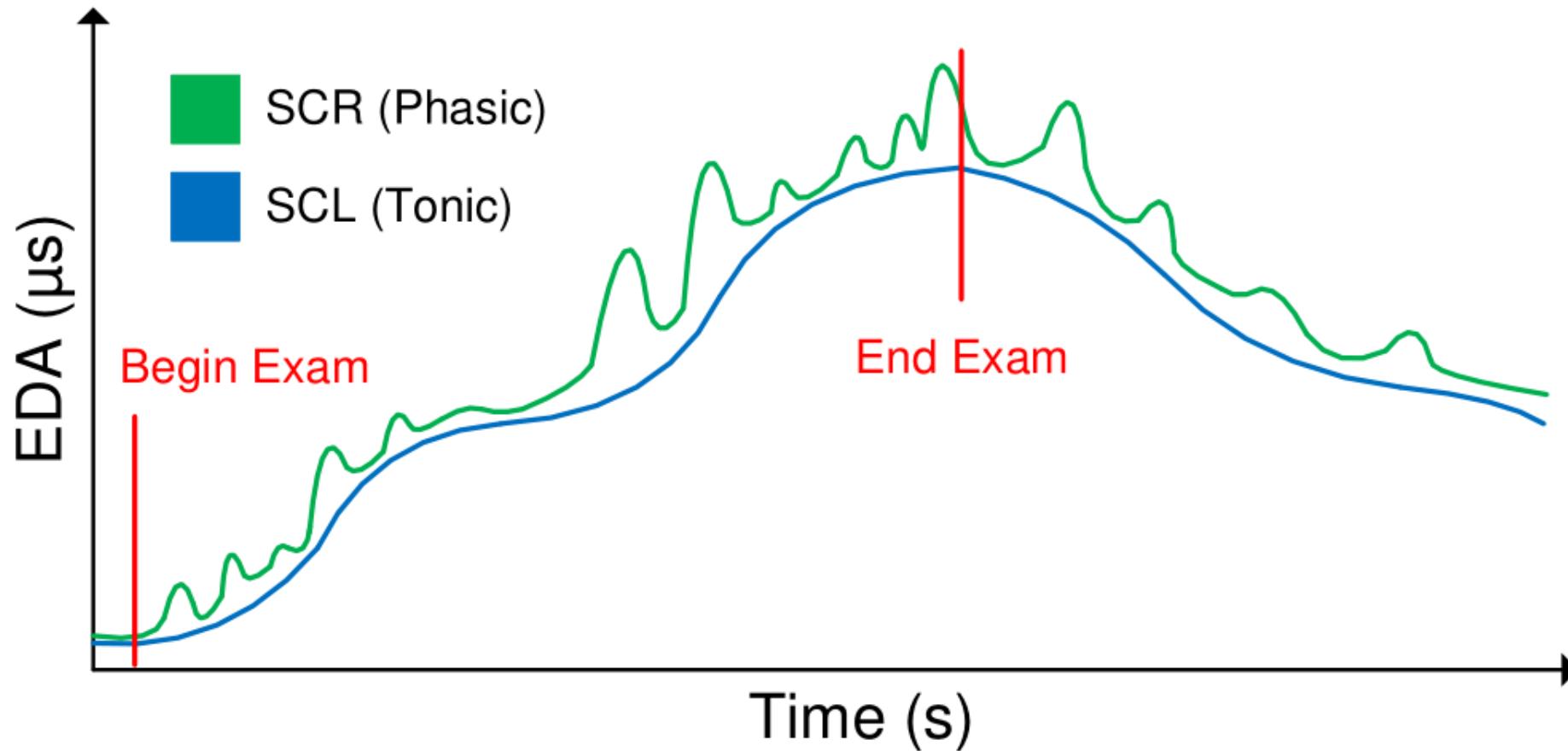
These are referred to as

- *skin conductance level* (SPL) and
- *skin conductance response* (SPR), respectively.

Care needs to be taken of the differences in magnitude.

# Psychophysiology: Electrodermal activity: Analysis

## Tonic vs phasic changes



# Psychophysiology: Electrodermal activity: Analysis

## Tonic parameters

The SCL itself varies greatly between individuals.

Interpreting it as “general arousal level” is therefore wrong.

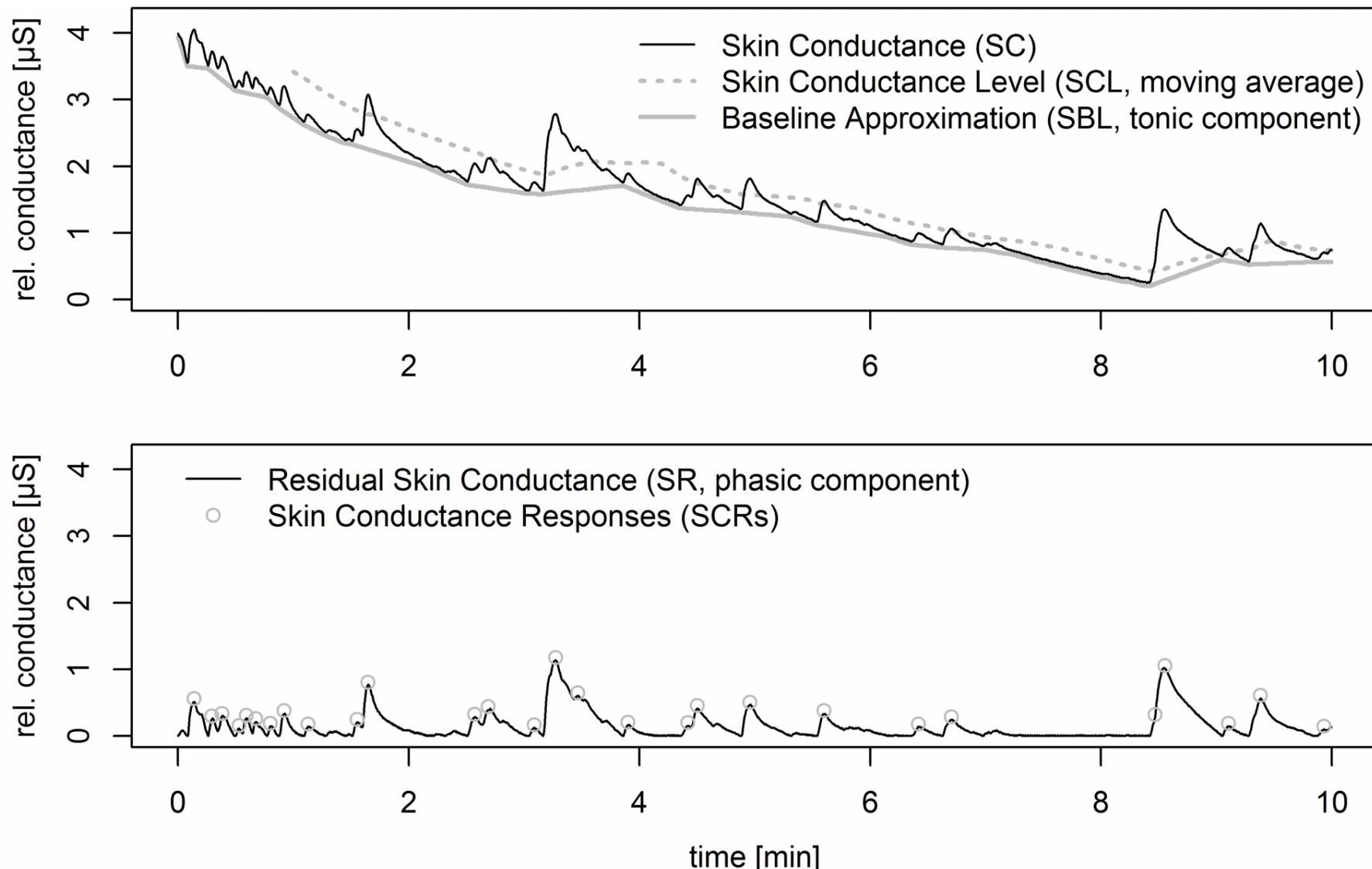
Within-subjects relative SCL difference however may be indicative of changes in arousal.

A possibly more reliable measure of general arousal is the *rate of non-specific fluctuations*, e.g. per minute.

A non-specific fluctuation is defined as occurring e.g. more than 5 seconds after any known stimulus, including artefactual ones (e.g. breathing-related events).

# Psychophysiology: Electrodermal activity: Analysis

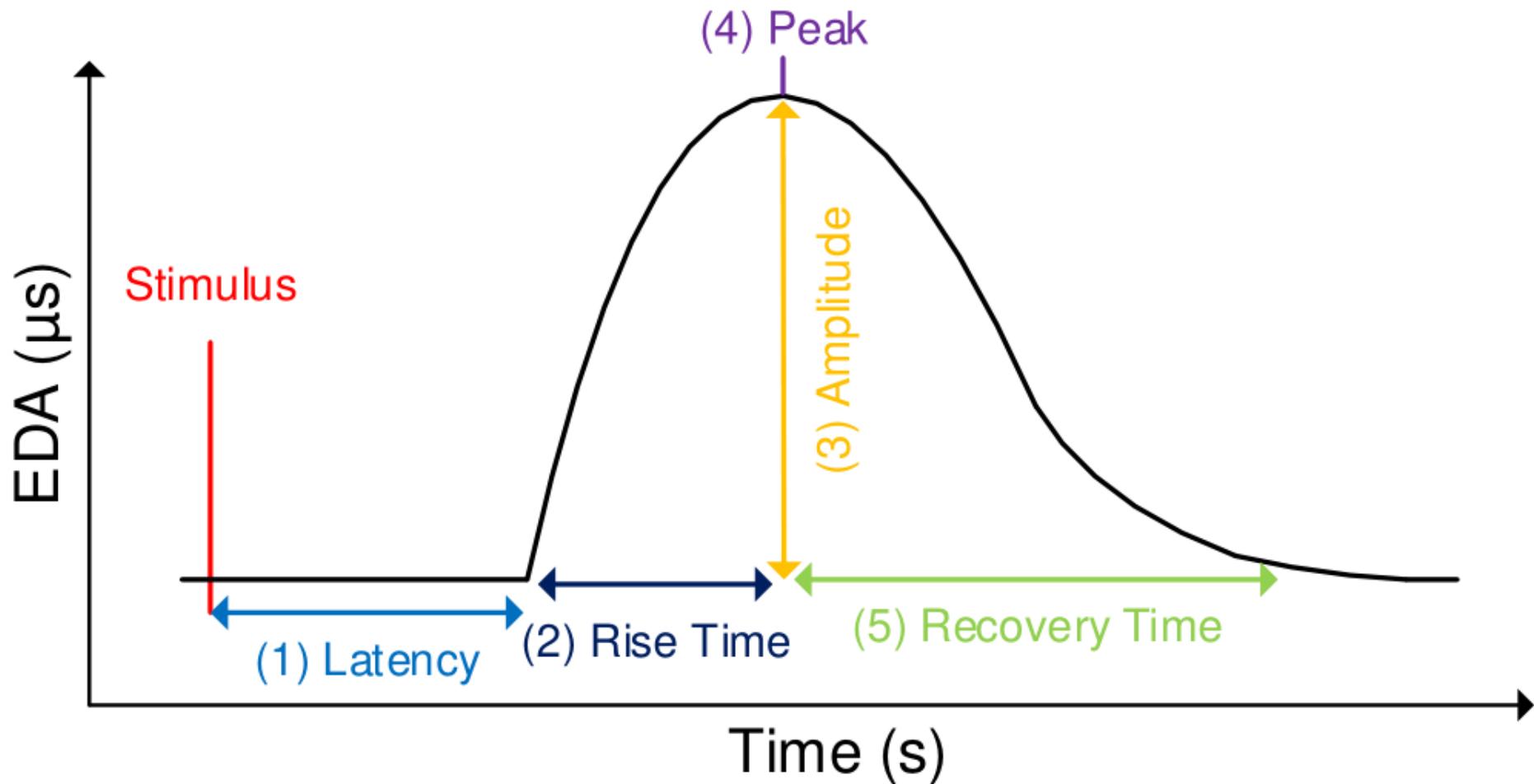
## Tonic versus phasic changes



Leiner, D., Fahr, A., & Früh, H. (2012). EDA positive change: A simple algorithm for electrodermal activity to measure general audience arousal during media exposure. *Communication Methods and Measures*, 6(4), 237-250.

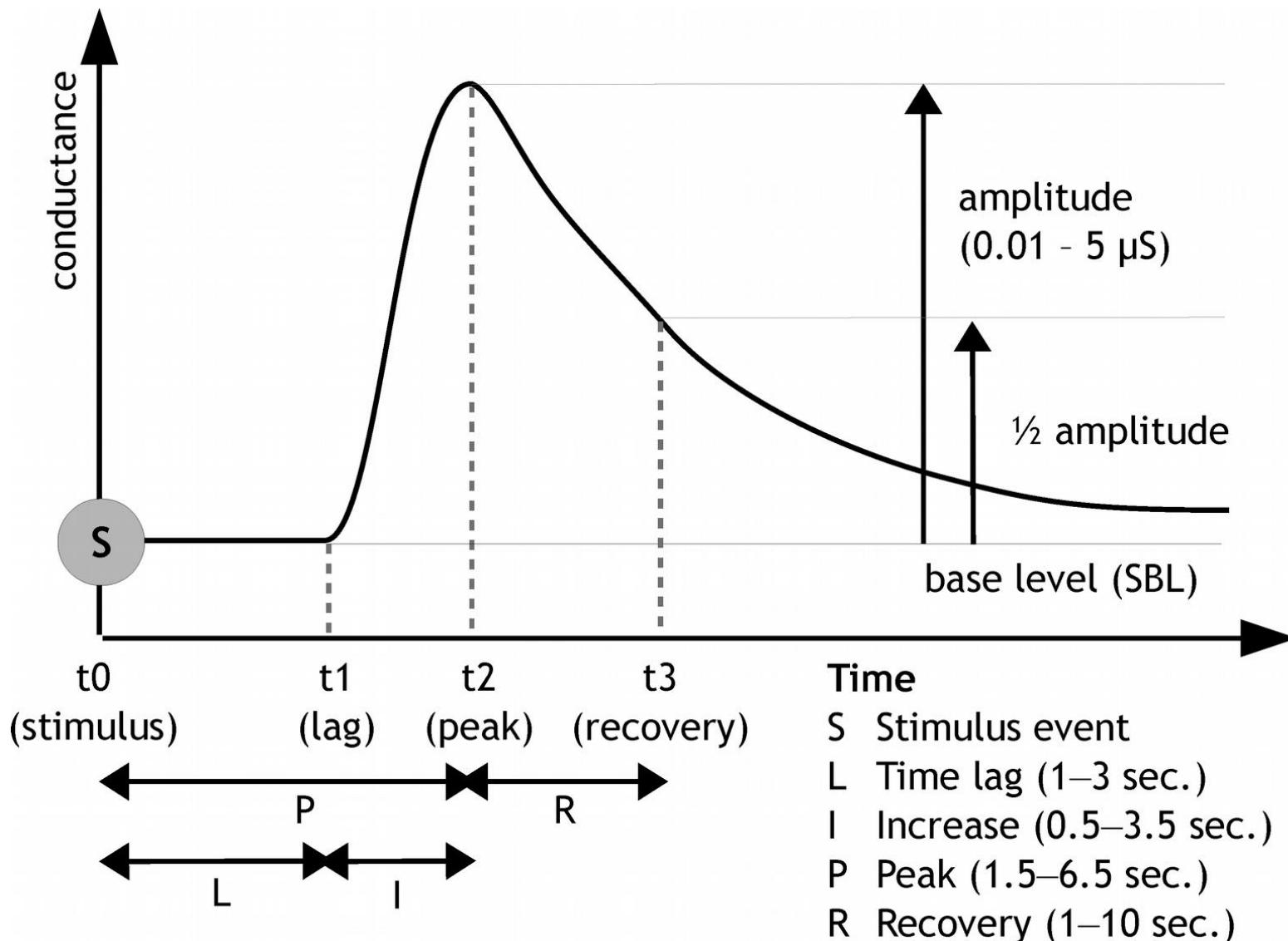
# Psychophysiology: Electrodermal activity: Analysis

## Phasic parameters



# Psychophysiology: Electrodermal activity: Analysis

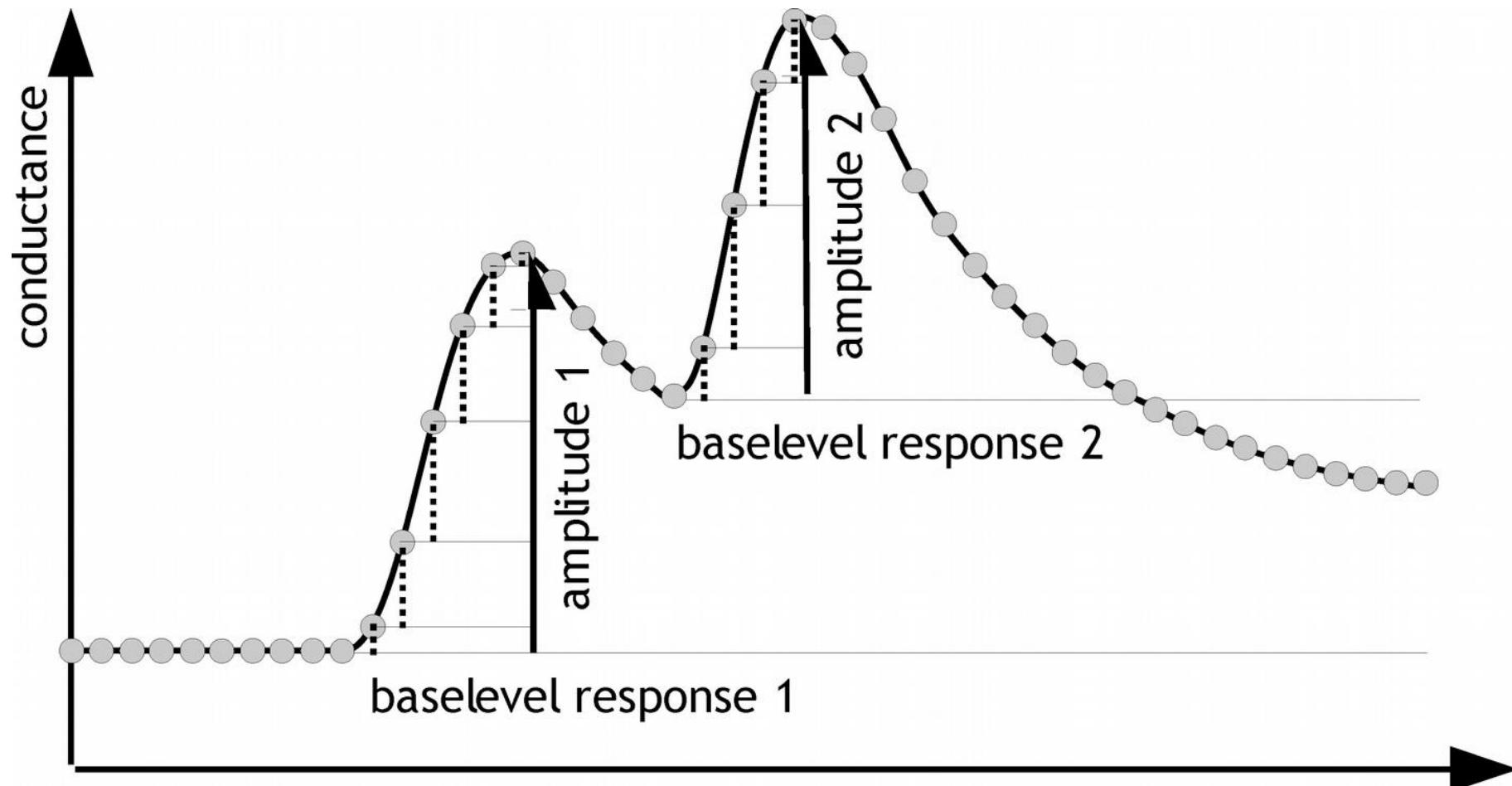
## Phasic parameters



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# Psychophysiology: Electrodermal activity: Analysis

## Phasic parameters

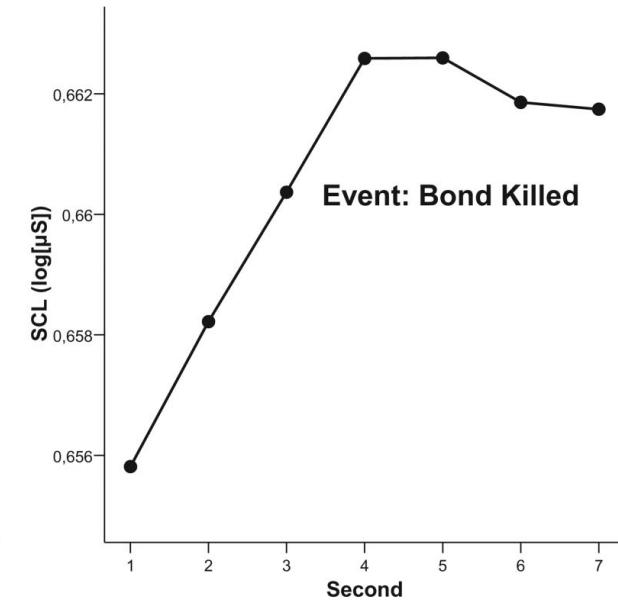
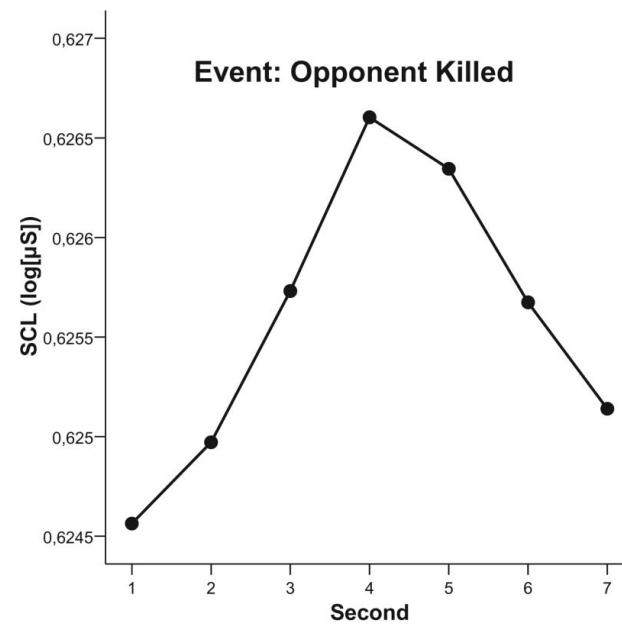
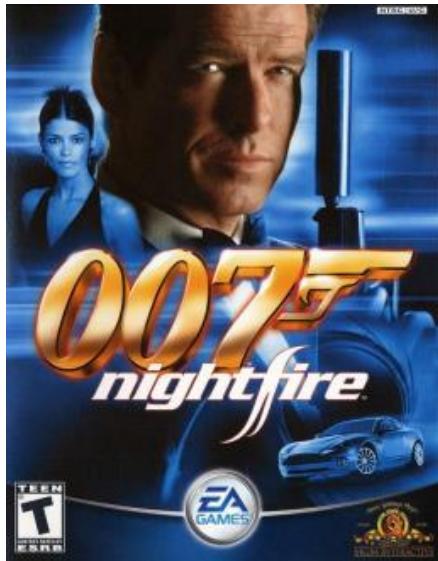


- Measuring point (at 10 Hz sample rate)
- ⋮ Positive change in skin conductance between two measuring points

Leiner, D., Fahr, A., & Früh, H. (2012). EDA positive change: A simple algorithm for electrodermal activity to measure general audience arousal during media exposure. *Communication Methods and Measures*, 6(4), 237-250.

# Psychophysiology: Electrodermal activity: Analysis

## Sample study: James Bond 007

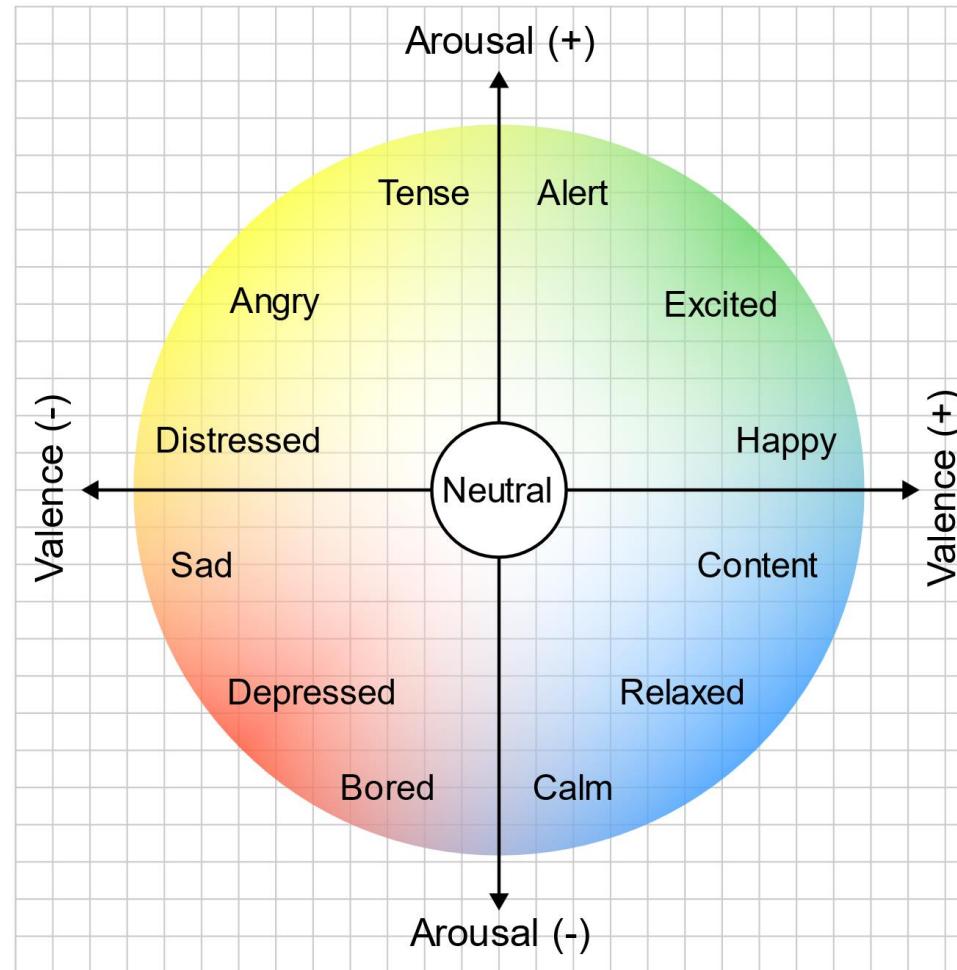


Cover figure: © Eurocom Entertainment Software / Electronic Arts

Ravaja, N., Turpeinen, M., Saari, T., Puttonen, S., & Keltikangas-Järvinen, L. (2008). The psychophysiology of James Bond: Phasic emotional responses to violent video game events. *Emotion, 8*(1), 114.

# Psychophysiology: Electrodermal activity: Analysis

## James Russell's circumplex model of emotion

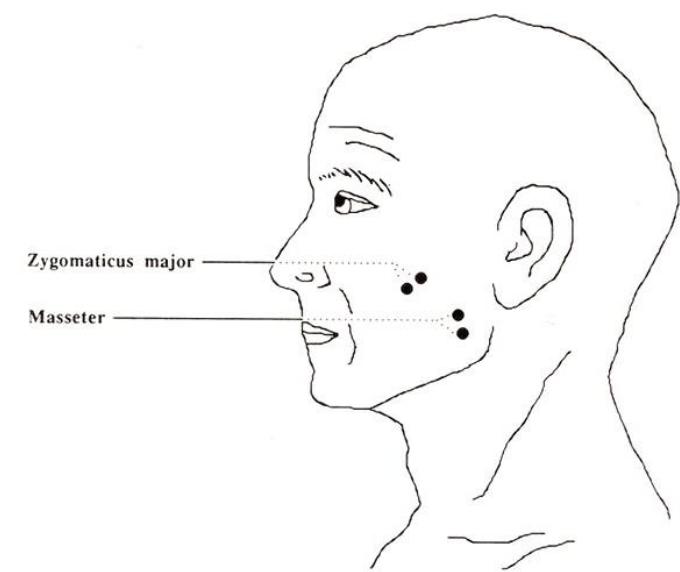
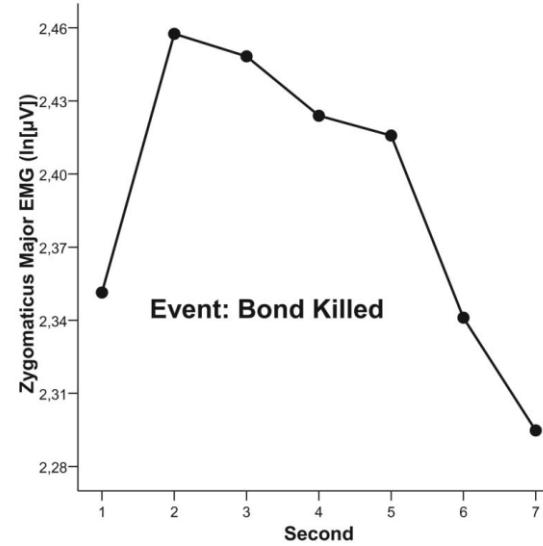
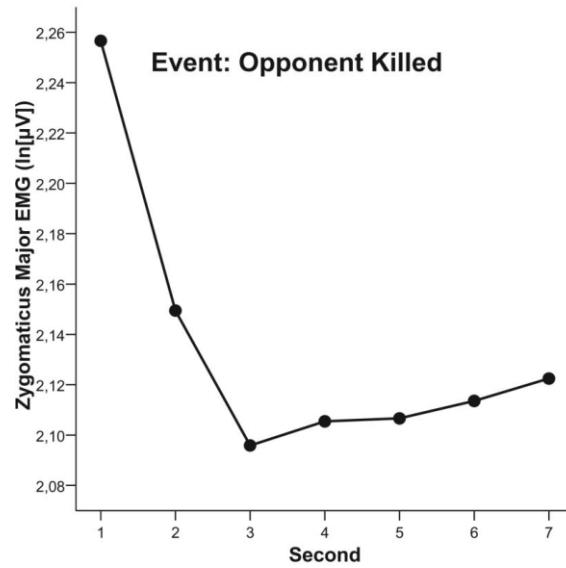
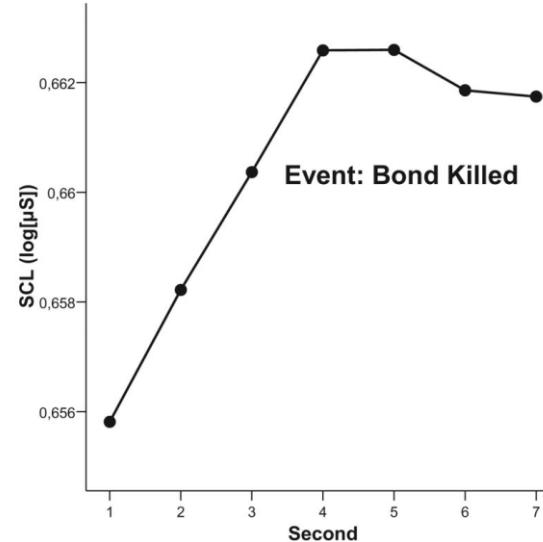
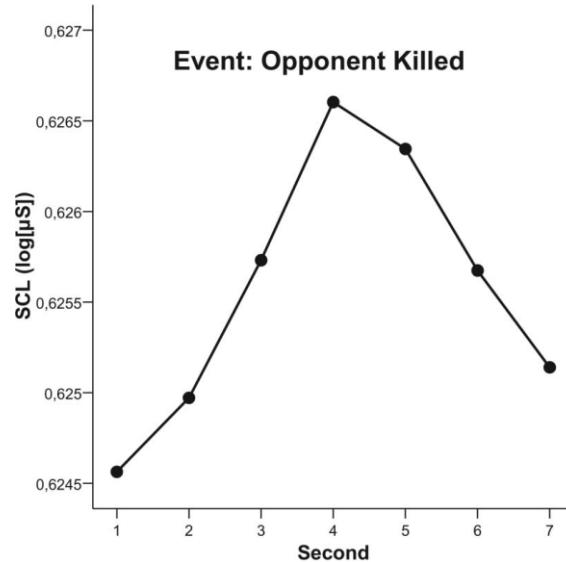


Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, 39(6), 1161–1178.

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# Psychophysiology: Electrodermal activity: Analysis

## Sample study: James Bond 007



# Psychophysiology

## Electrodermal activity

The activity of eccrine sweat glands, particularly prevalent on palms and soles, has psychological correlates.

This activity can be measured continuously as changes in skin conductance.

Parameters of the event-related skin conductance response (SCR) are of primary interest for psychophysiological research.

# Psychophysiology

## Part 7: Electrodermal activity



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