

Sensomotorik: EMG und EMS
Für den privaten Gebrauch

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Grundlagen der Sensomotorik zur funktionellen Elektrostimulation: vom EMG zur EMS



Univ. Prof. Dr.
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Physical Medicine & Rehabilitation
Physical Sportsmedicine

Koblenz, 3.9.2022

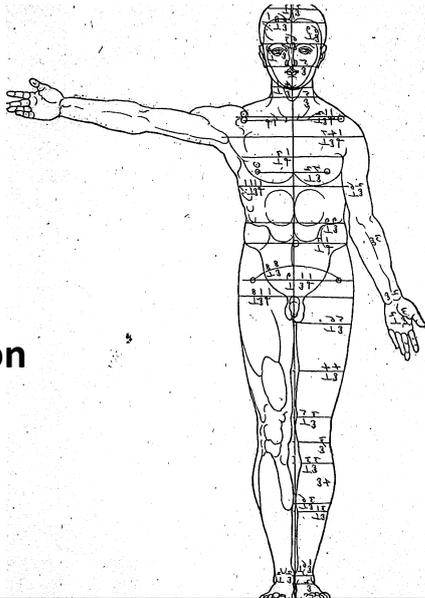
AG ELEKTROTHERAPIE



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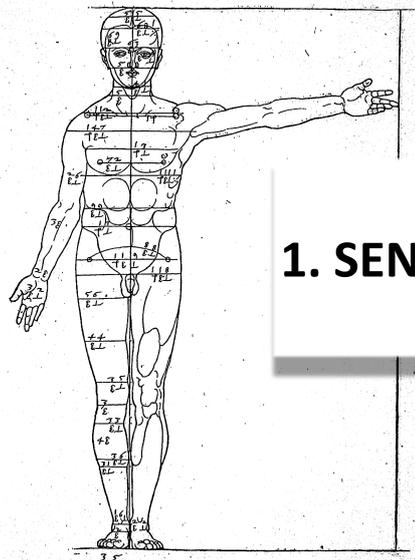
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1. Sensomotorik
2. EMG
3. EMS
4. „funktionelle“ Stimulation
5. Ausblicke



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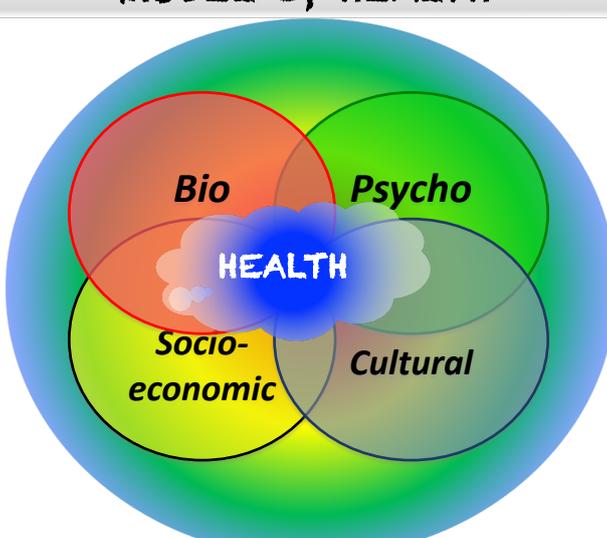


1. SENSOMOTORIK MODELL

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BIO - Psycho - Socio-Economic - Cultural MODEL of HEALTH



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PRIMÄRES ZIEL: GESUNDHEIT

SEKUNDÄRES ZIEL: BEWEGUNG

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Definitionsvorschlag:
GESUNDHEIT: Ergebnis aus subjektiver und objektiver Beurteilung der Funktionsfähigkeit und des Befindens einer lebendigen Person

BEWEGUNG:

allgemein:	Veränderung eines Objekts in Form und Raum Veränderung der Verteilung von Elementen in Systemen
klassische Mechanik:	Dynamik: Bewegung von Körpern in Abhängigkeit von einwirkenden Kräften
technische Mechanik:	Dynamik als Lehre von den Bewegungen fester Körper Kinematik → Bewegungsbahnen Kinetik → Krafteinwirkung

BEWEGUNG = f (Struktur, Information, Energie)
B = f (S,I,E)

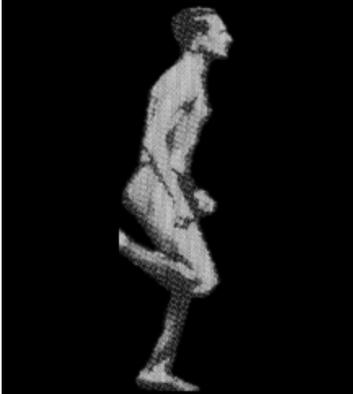
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Was ist menschliche Bewegung, was macht diese aus Was bestimmt menschliche Mobilität

Monthly Python
1978

Ministry of silly walks



Edward Muybridge
1878



KOORDINATION VON SENSORISCHER UND MOTORISCHER INFORMATION



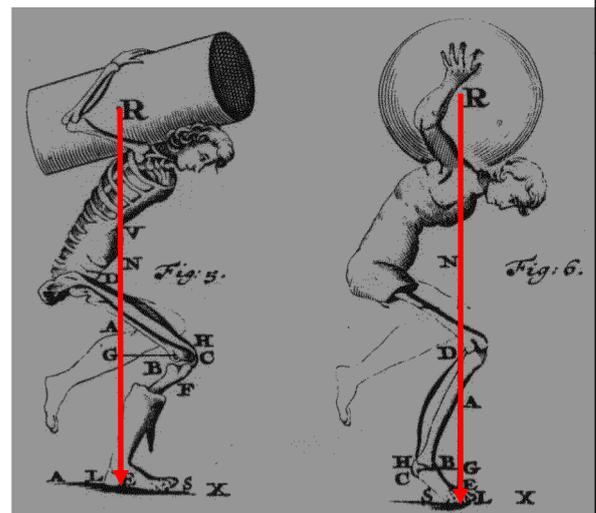
René Descartes' *Traite de l'homme*
(Treatise of Man) 1664

Giovanni Alfonso Borelli 28 January 1608 - 31 December 1679, Neapel



JOH. ALPHONSI BORELLI
Neapolitani Mathematici Professoris
DE
**MOTU
ANIMALIUM**
PARS PRIMA.
EDITIO NOVISSIMA,
Ab innotuitis mendis & erroribus reposita.
Addita sunt postquam Parisi Secunda.
JOHANNIS BERNOULLII
Mathematici
Meditationes Mathematicae
DE MOTU MUSCULORUM.

LUGDUNI BATAVORUM,
Apud **PETRUM VANDER AER**, Bibliopolam.
ANNO M DCC X.



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→ **Center of mass**

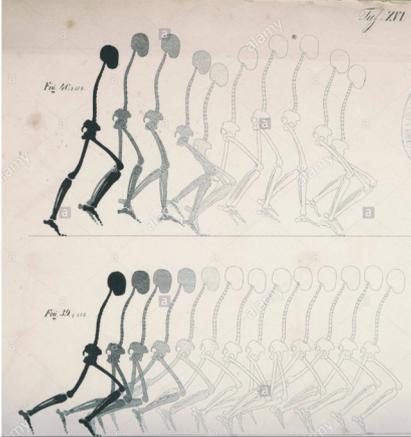
Eduard Friedrich Weber
(10.3. 1806 - 18.5 1871)
Wilhelm Eduard Weber
(24.10.1804 - 23.6.1891)

Mechanik
der
menschlichen
Gehwerkzeuge.

Eine
anatomisch-physiologische Untersuchung
von den Brüdern
Wilhelm Weber
Professor in Göttingen
und
Eduard Weber
Professor in Leipzig.

Nebst einem Hefte mit 17 Tafeln anatomischer Abbildungen.

Göttingen,
in der Dieterichschen Buchhandlung.
1836.





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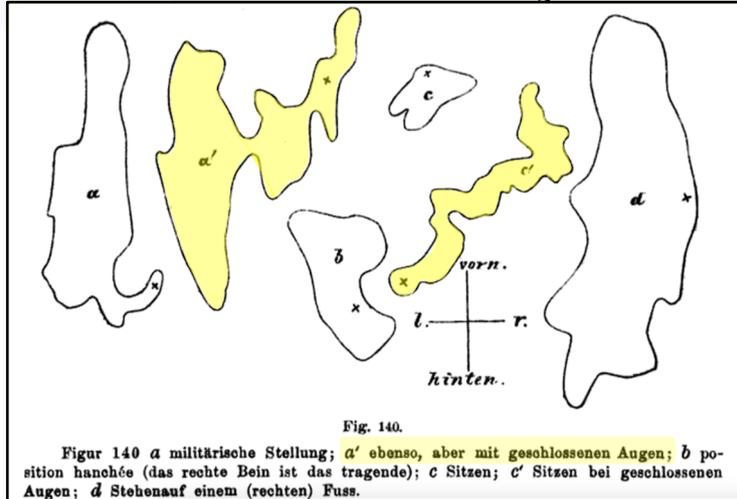
Karl von Vierordt
(* 1. Juli 1818 in Lahr, Baden; † 22. November 1884 in Tübingen)

- postural control is not the effect of **one sense** but of a whole series of sensitivo-sensorial data: **visual, tactile from the sole of the feet, proprioceptives.**
- The recordings of the posture of man standing at rest are likely to inform us on the functioning of what is not yet called postural system but already exists as a nearly complete concept
- he recorded the very first stabilometric signals.

First stabilometric recordings.
Vierordt kept only the envelope of the drawing made through the feather worn by the standing subject, in the eyes open (a) and closed condition (a'); in the «position hanchée», the right leg being the support (b); sitting eyes open (c) and closed (c'); standing on the only right foot (d).

Vierordt Karl, Grundriss der Physiologie des Menschen. 1871 Tübingen, p:445-446

First stabilometric recordings.



Vierordt Karl, Grundriss der Physiologie des Menschen. 1871 Tübingen, p:445-446

„... Beiliegende Figuren geben Proben dar, am Scheitel gemessen, Schwankungen bei den verschiedenen Stellungen.
Das * bezeichnet die Anfangsstellung des Pinsels. Die Versuchszeit betrug immer 3 Minuten; bei Verlängerung derselben würden die Vorzüge der asymmetrischen Stellungen noch mehr hervortreten...“

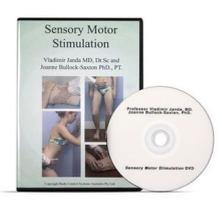
Viktor v. Weizsäcker (1886 – 1957): 1922

„...Reflexes are somehow elements or components of sensorimotor basic functions...“

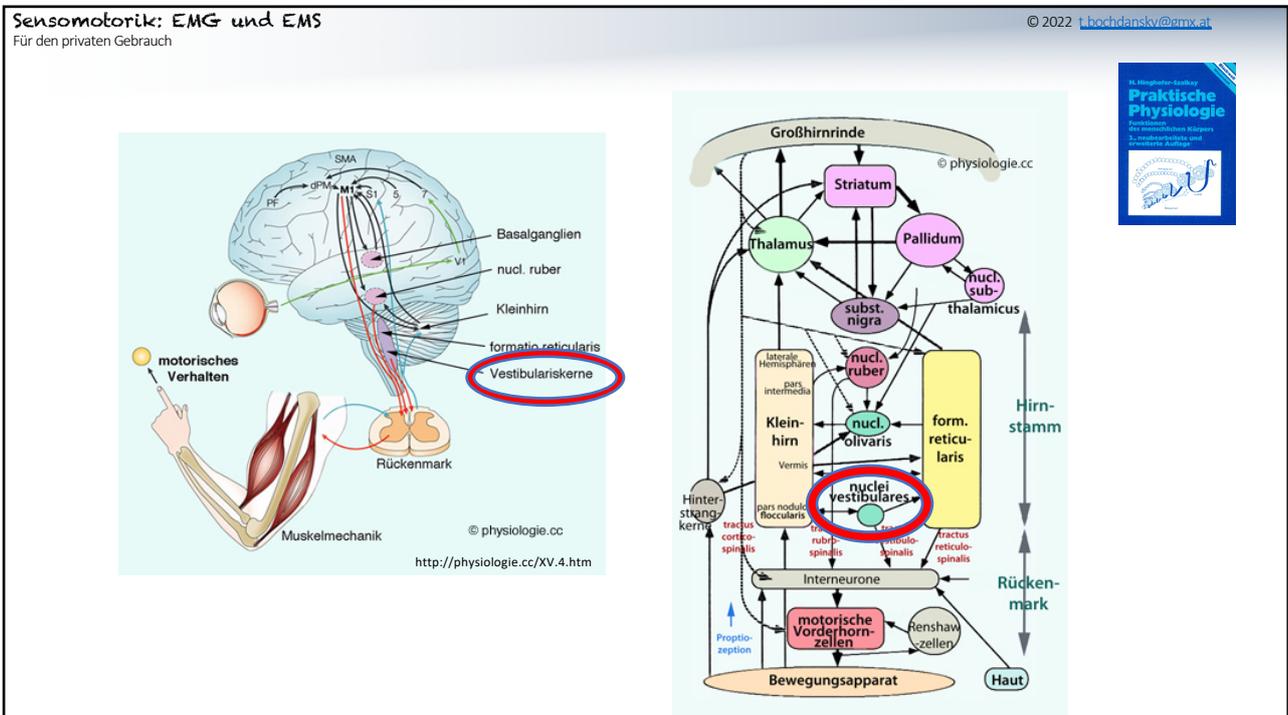
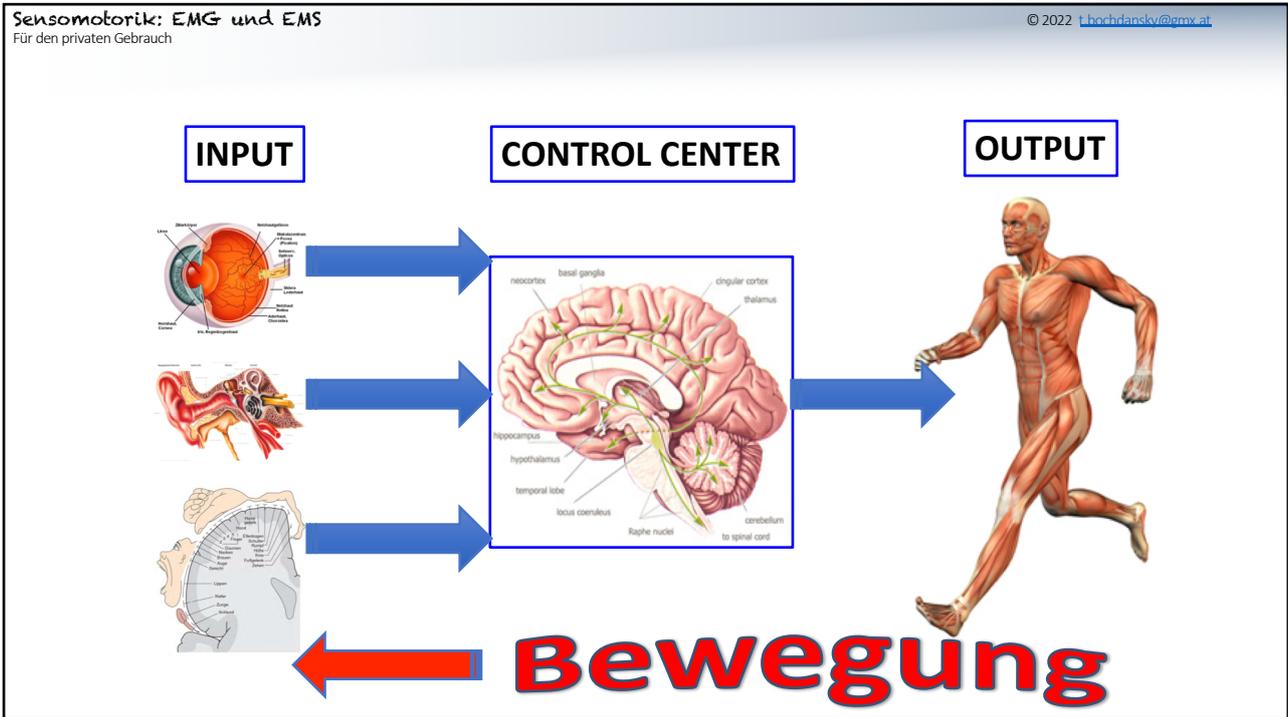


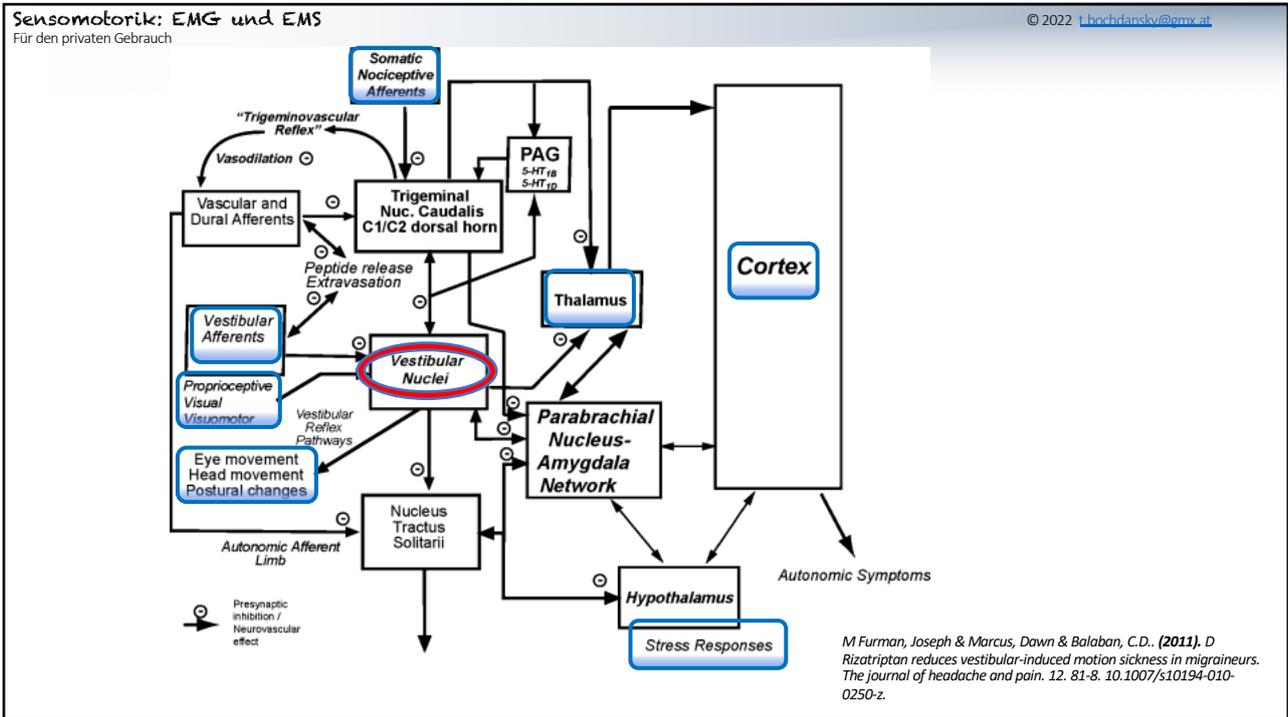
Vladimir Janda (1928 – 2002): 1984

„sensory motor Fazilitation“



Haase J., Henatsch H.D., Jung R., Strata P., Thoden U.: 1976
„Sensomotorik“,
Urban & Schwarzenberg, Physiologie des Menschen, Band 14





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NUCLEUS VESTIBULARIS

FUNCTION:

- in conjunction with the cerebellum –
- to maintain equilibrium and posture,
- convey perception of head position and acceleration,
- modify muscle tone.

3 main input information:

- Visual
- Vestibular
- somatosensory

Abb. 20 Anatomisches Substrat des Gleichgewirns. Es sind die Verbindungen der optischen Bahnen zu den motorischen Zentren und von da zum Hirnstamm und zu den Augenmuskeln einerseits dargestellt, andererseits die Beziehungen von Kleinhirn und Vestibularapparat zum Hirnstamm und Rückenmark und schließlich die propriozeptiven Afferenzen aus den unteren Extremitäten und der Wirbelsäule.

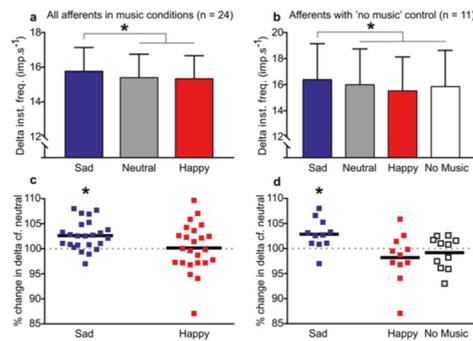
Bassetti, Mumenthaler: Thieme, 2012

Emotions alter muscle proprioceptive coding of movements in humans (Aug. 2017)

... muscle afferent firing was modified by the emotional context, especially for sad emotions, where the muscle spindle dynamic response increased.

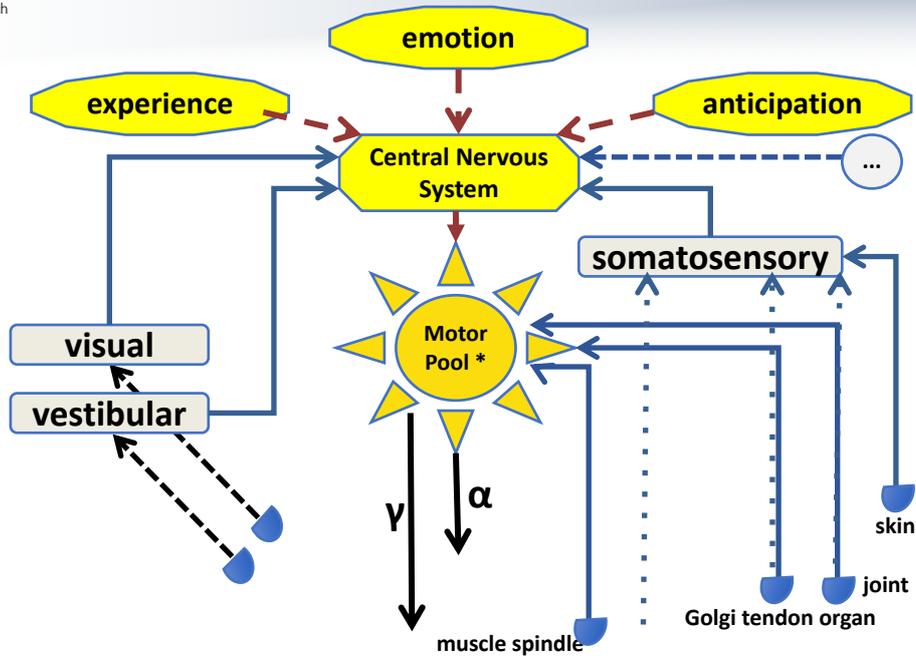
We suggest that this allows us to prime movements, where the emotional state prepares the body for consequent behaviour-appropriate reactions.

Figure 2



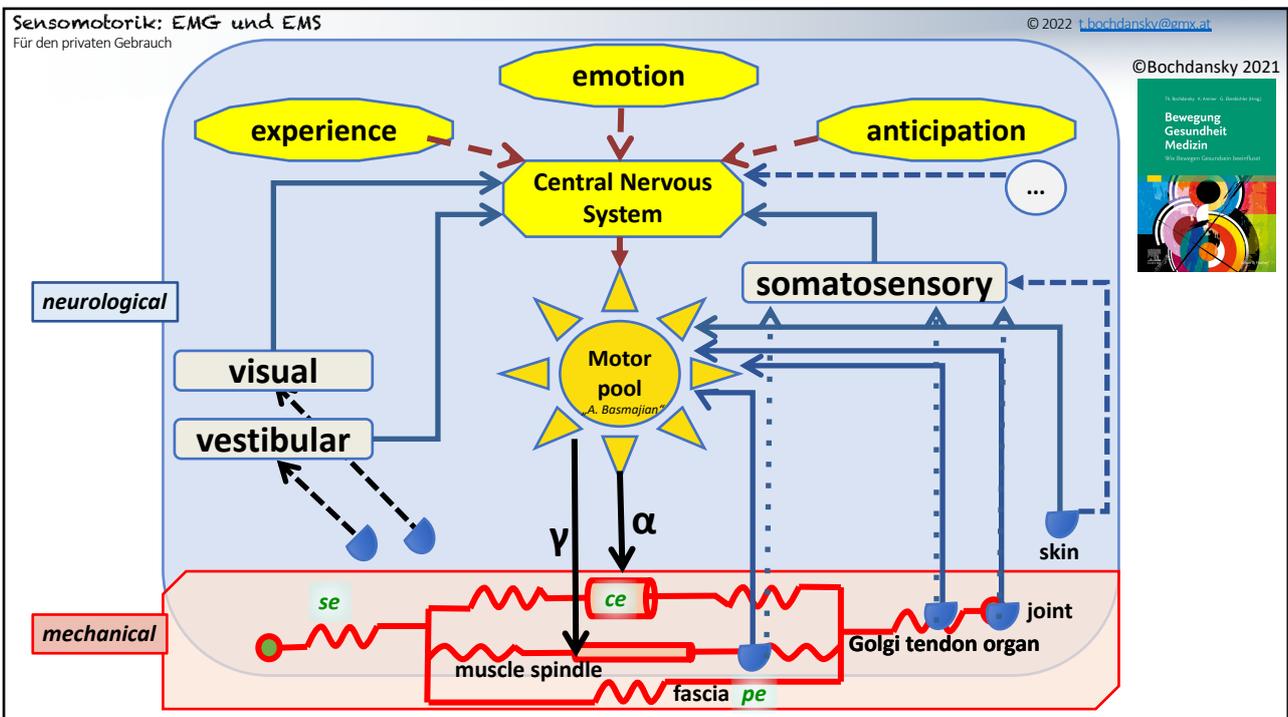
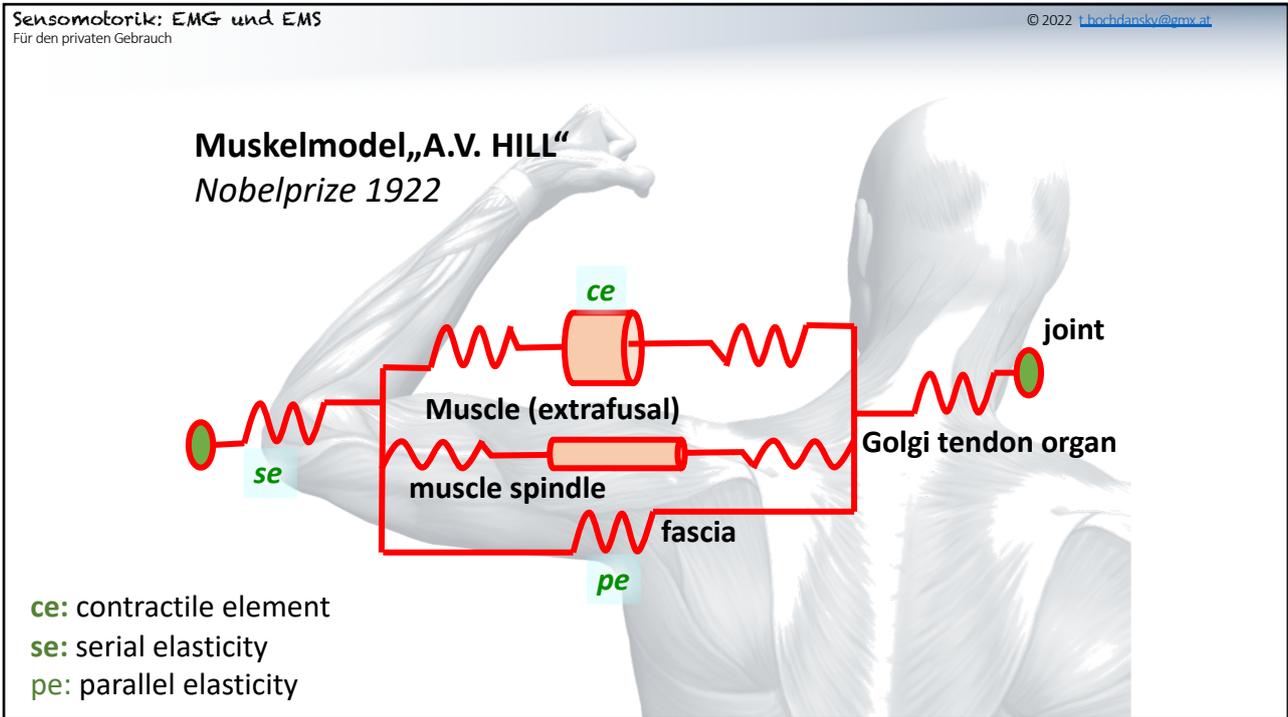
Ackerley R, Aimonetti JM, Ribot-Ciscar E. Emotions alter muscle proprioceptive coding of movements in humans. Sci Rep. 2017 Aug 16;7(1):8465. <https://www.nature.com/articles/s41598-017-08721-4>

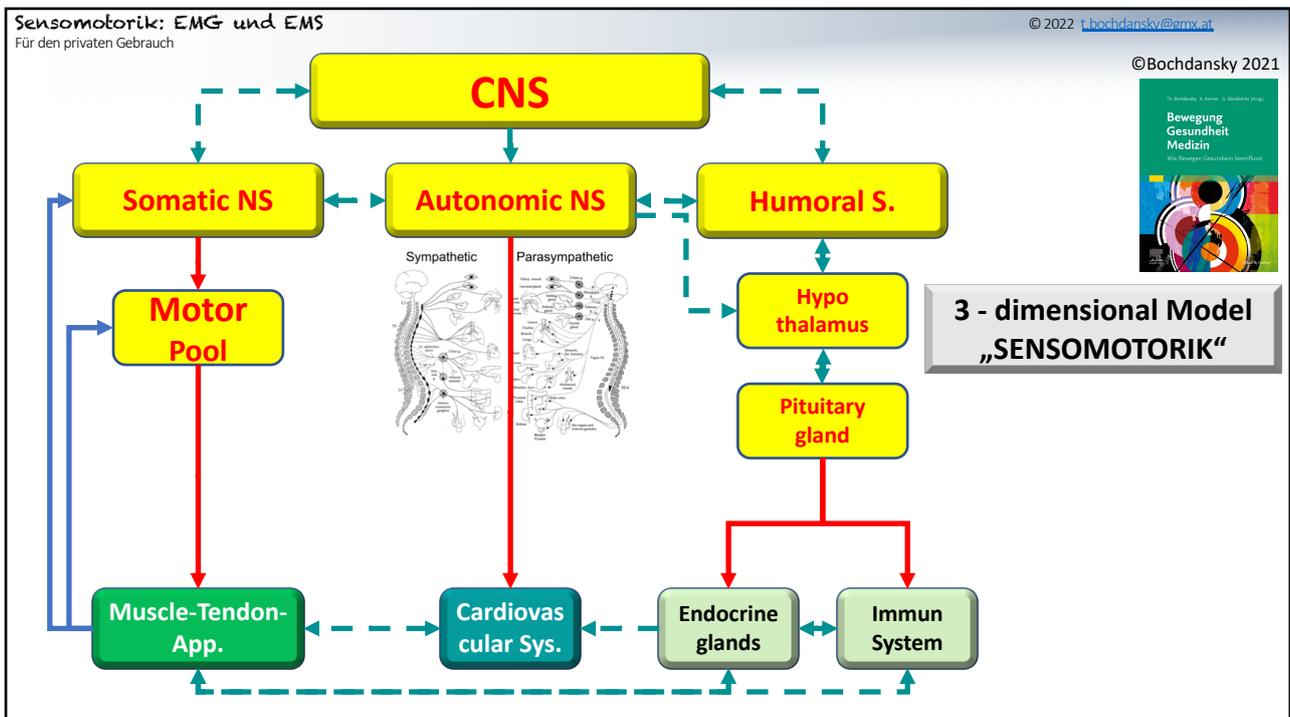
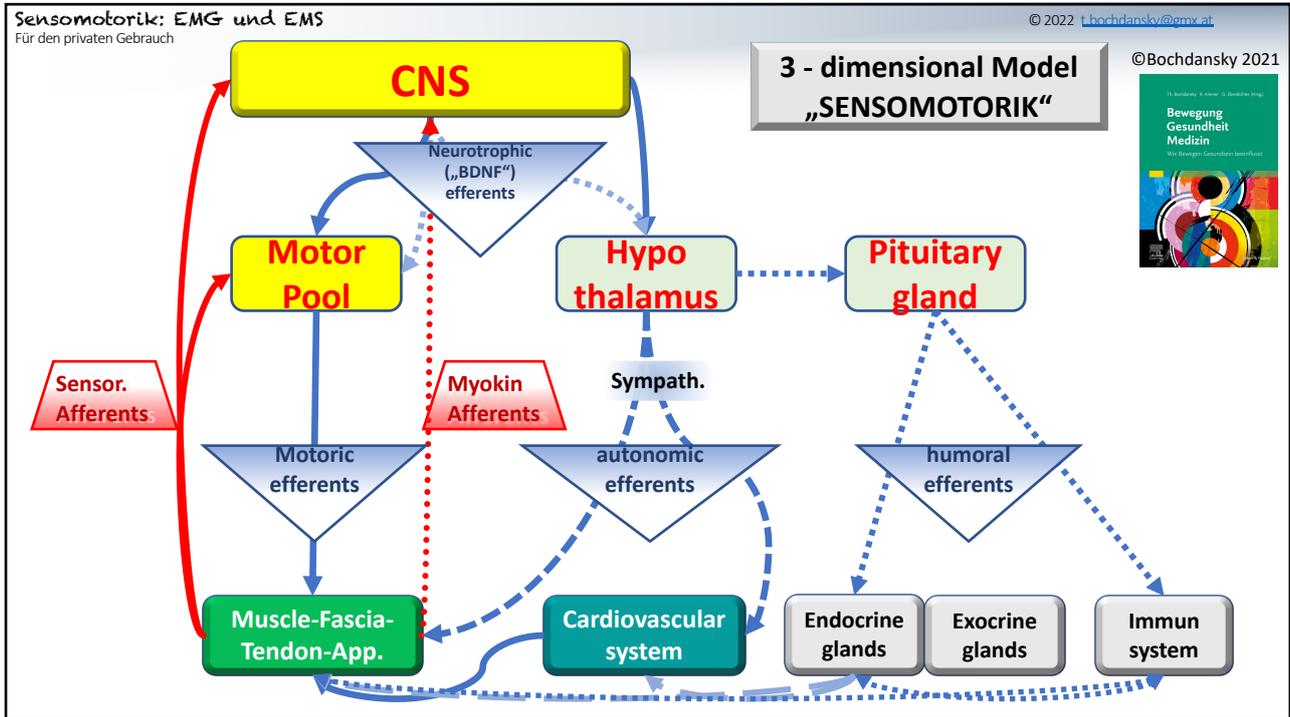
Modulation of the muscle afferent dynamic responses over the conditions for the full group of units (left) and a sub-set with the additional no music condition (right). The top graphs show the overall changes in instantaneous firing frequency (delta). (a) A significant increase in delta was found during the sad condition, over the neutral and happy conditions for all units, which was also found in (b) the sub-set with the additional no music condition. Means with SEM are shown. The bottom row shows the spread of the population. (c) The distribution of delta (as a percentage) in comparison to the neutral music condition for all units. (d) The same distributions are shown for the sub-set of units with no music condition. In both (c) and (d), the delta in the sad condition was significantly increased. *p < 0.05.



Bochdanskv, 1994

(* Basmajian)

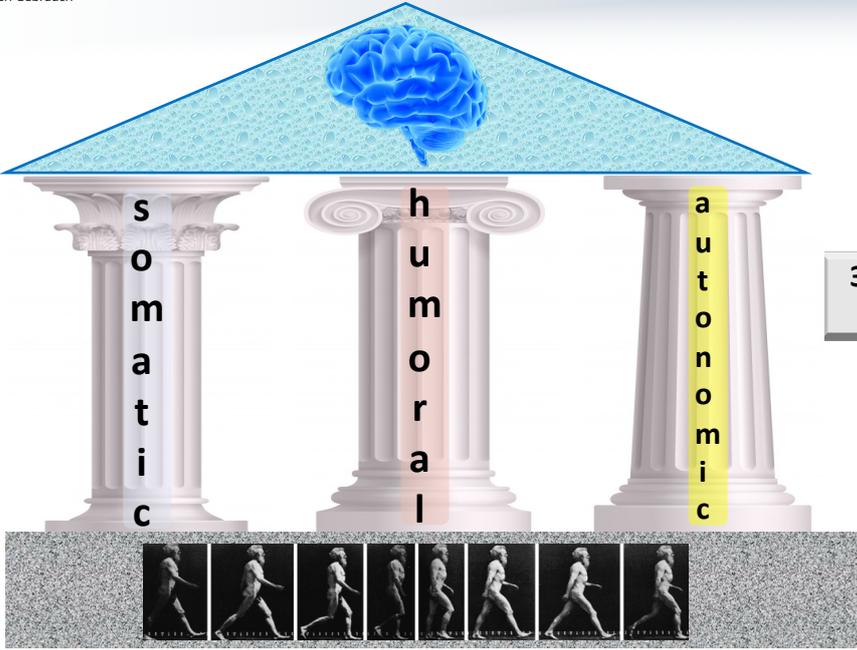




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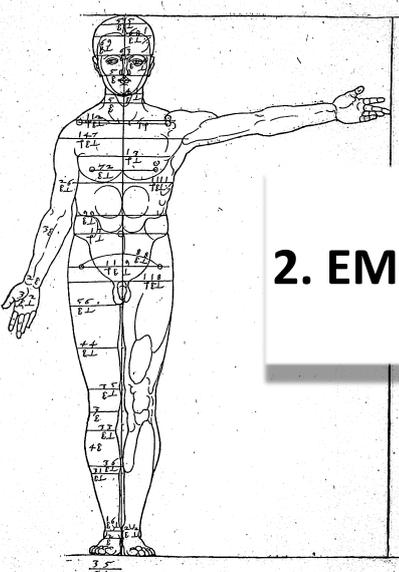


The diagram illustrates a 3-dimensional model of sensomotorik. It features a classical temple structure with three columns. The left column is labeled 'somatic', the middle column 'humoral', and the right column 'autonomic'. Above the columns is a triangular pediment containing a blue brain. Below the columns is a horizontal strip of eight sequential images showing a person walking. To the right of the columns is a grey box containing the text '3 - dimensional Model „SENSOMOTORIK“'. In the top right corner, there is a small book cover titled 'Bewegung Gesundheit Medizin'.

3 - dimensional Model „SENSOMOTORIK“

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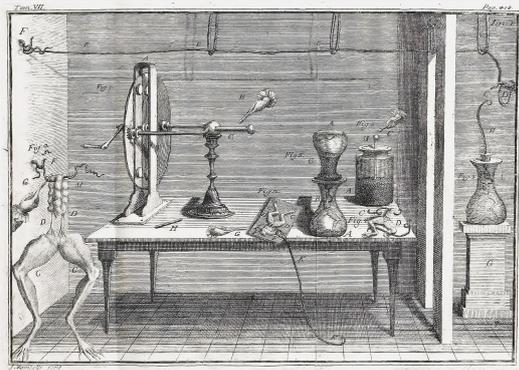
The diagram shows a human figure with various points marked for EMG electrode placement. The points are labeled with numbers and letters, such as '1-12', '1-13', '1-14', '1-15', '1-16', '1-17', '1-18', '1-19', '1-20', '1-21', '1-22', '1-23', '1-24', '1-25', '1-26', '1-27', '1-28', '1-29', '1-30', '1-31', '1-32', '1-33', '1-34', '1-35', '1-36', '1-37', '1-38', '1-39', '1-40', '1-41', '1-42', '1-43', '1-44', '1-45', '1-46', '1-47', '1-48', '1-49', '1-50', '1-51', '1-52', '1-53', '1-54', '1-55', '1-56', '1-57', '1-58', '1-59', '1-60', '1-61', '1-62', '1-63', '1-64', '1-65', '1-66', '1-67', '1-68', '1-69', '1-70', '1-71', '1-72', '1-73', '1-74', '1-75', '1-76', '1-77', '1-78', '1-79', '1-80', '1-81', '1-82', '1-83', '1-84', '1-85', '1-86', '1-87', '1-88', '1-89', '1-90', '1-91', '1-92', '1-93', '1-94', '1-95', '1-96', '1-97', '1-98', '1-99', '1-100'. A large grey L-shaped graphic is positioned to the right of the figure, with the text '2. EMG' inside it.

2. EMG

HISTORY:

Luigi GALVANI: 1737 – 1798

„De viribus electricitatis in motu musculari“ (1791)



Carlo Matteucci (1811 – 1868)

Trattato dei fenomeni elettrofisiologici degli animali. 1844.

empfindlichen Galvanometer von **Leopoldo Nobili** (1784 – 1835)

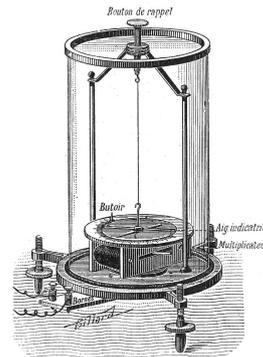


Fig. 335. — Galvanomètre de Nobili.

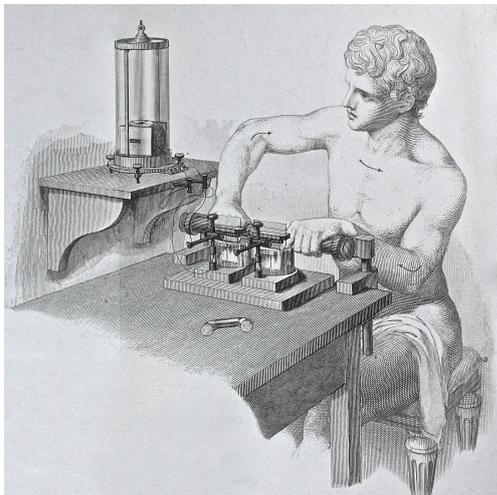
https://hr.wikipedia.org/wiki/Leopoldo_Nobili#/media/Datoteca:Galvanomètre_de_Nobili.jpg

astatic galvanometer, invented by Leopoldo Nobili in 1825

Johannes Peter Müller (1801 - 1858), Berlin

Emil du Bois-Reymond (1818 – 1896), Berlin

1842 gelang ihm der Nachweis der „tierischen Elektrizität“



Photograph of Paul du Bois-Reymond, Emil's younger brother, demonstrating tetanic currents in his own body.

Gabriel Finkelstein: M. du Bois-Reymond goes to Paris 2003



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Emil du Bois-Reymond : 1848

John V. Basmajian, (1921–2008)

1. ed.: 1848

2. ed.: 1849

1. ed.: 1962

5. ed.: 1985

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De Luca, Carlo J.
"The use of surface electromyography in biomechanics."
Journal of applied biomechanics 13.2 (1997): 135-163.
Wartenweiler Memorial Lecture, ISB, 1993

FACTORS

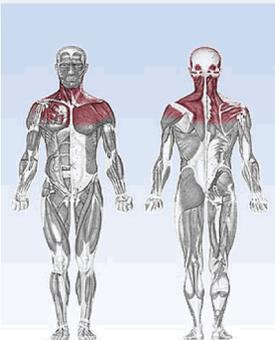
CAUSATIVE	INTERMEDIATE	DETERMINISTIC	EMG SIGNAL	INTERPRETATION
<p>EXTRINSIC</p> <ul style="list-style-type: none"> ELECTRODE: <ul style="list-style-type: none"> · CONFIGURATION · MOTOR POINT · MUSCLE EDGE · FIBER ORIENT. · TENDON <p>INTRINSIC</p> <ul style="list-style-type: none"> NUMBER ACTIVE MU MU FIRING RATE (SYNCHRONIZATION) FIBER TYPE LACTIC ACID (pH) BLOOD FLOW FIBER DIAMETER ELECTRODE FIBER LOCATION SUBCUTANEOUS TISSUE OTHER FACTORS 	<ul style="list-style-type: none"> DIFF. ELECTRODE FILTER DETECTION VOLUME SUPERPOSITION SIGNAL CROSSTALK CONDUCTION VELOCITY SPATIAL FILTERING 	<ul style="list-style-type: none"> NUMBER ACTIVE MU MU FORCE TWITCH MUSCLE FIBER INTERACTIONS MU FIRING RATE NUMBER DETECTED MU MUAP AMPLITUDE MUAP DURATION MUAP SHAPE RECRUITMENT STABILITY 	<ul style="list-style-type: none"> AMPLITUDE (RMS/ARV) SPECTRAL VARIABLES (MEDIAN MEAN FREQ.) 	<ul style="list-style-type: none"> MUSCLE FORCE (FORCE-NET TORQUE) MUSCLE ACTIVATION (ON/OFF) MUSCLE FATIGUE MUSCLE BIOCHEM.

Figure 1 - A schematic diagram of the factors which affect the EMG signal. The arrangement of the factors is designed to demonstrate the flow of the influences and interactions among the factors.

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Standards for Reporting EMG Data Author: Dr. Roberto Merletti, Politecnico di Torino, Italy

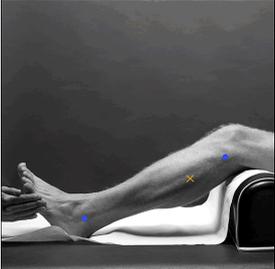
The SENIAM project (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles) is a European concerted action in the Biomedical Health and Research Program (BIOMED II) of the European Union.

<http://seniam.org>

-Electrode shape
-Electrode size
-Inter Electrode distance
-Electrode material
-Sensor construction

2 Möglichkeiten:

1. Intramuskuläres EMG
2. Oberflächliches EMG



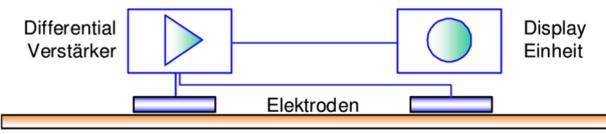
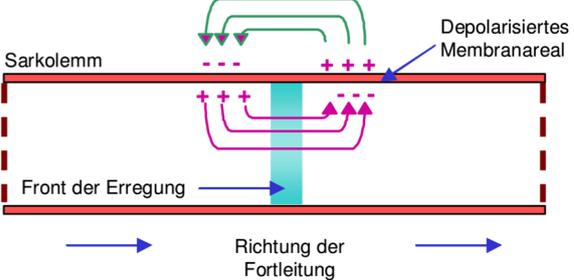
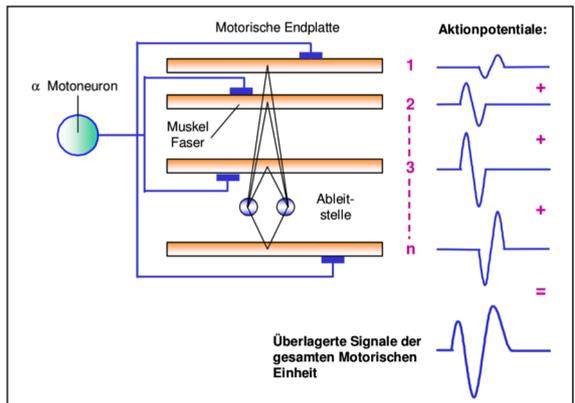
m. Peroneus longus

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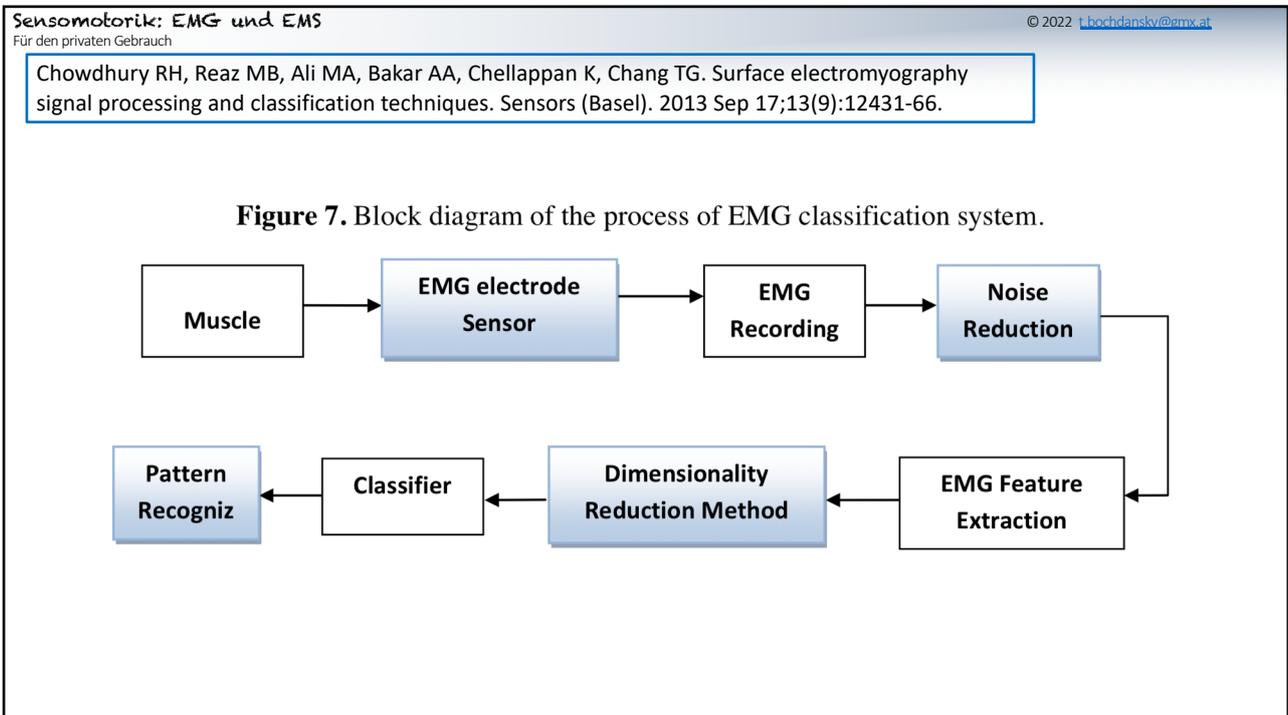
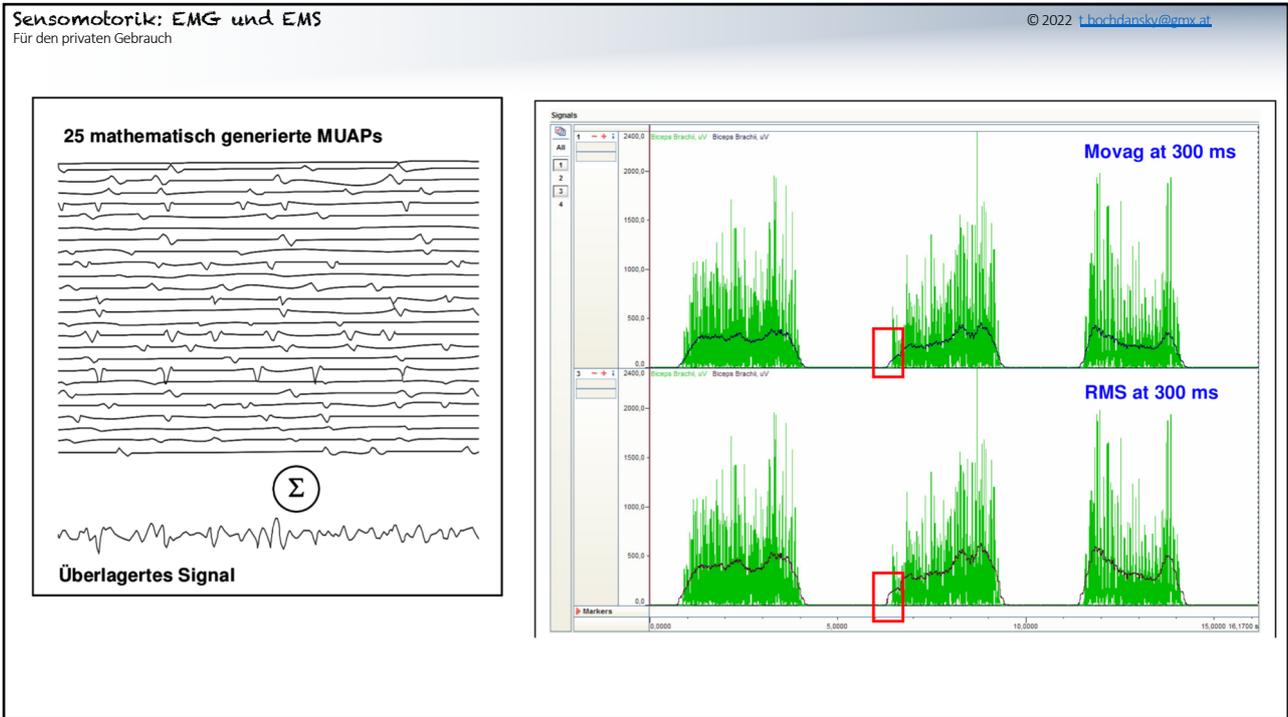
Peter Konrad: EMG – Fibel, 2011

Aktionspotentiale:

1 +
2 +
3 +
n +
=

Überlagerte Signale der gesamten Motorischen Einheit



Chowdhury RH, Reaz MB, Ali MA, Bakar AA, Chellappan K, Chang TG. Surface electromyography signal processing and classification techniques. Sensors (Basel). 2013 Sep 17;13(9):12431-66.

- Integrated EMG
- Mean absolute value
- Modified mean absolute value
- Simple square integral
- Variance of EMG
- Root mean square - RMS
- Waveform length
- Willison Amplitude
- Log detector
- Slope sign change
- Zero crossing
- multi scale amplitude

Table 4. Mathematical representation of widely used sEMG feature extraction methods.

Feature Extraction	Mathematical Equation
Integrated EMG (IEMG)	$IEMG = \sum_{i=1}^N x_i $ Here N denotes the length of the signal and x_i represents the sEMG signal in a segment.
Mean Absolute Value (MAV)	$MAV = \frac{1}{N} \sum_{i=1}^N x_i $
Modified Mean Absolute Value 1 (MMAV1)	$MMAV1 = \frac{1}{N} \sum_{i=1}^N w_i x_i $ $w_i = \begin{cases} 1, & \text{if } 0.25N \leq n \leq 0.75N \\ 0.5, & \text{otherwise} \end{cases}$
Modified Mean Absolute Value 2 (MMAV2)	$MMAV2 = \frac{1}{N} \sum_{i=1}^N w_i x_i $ $w_i = \begin{cases} 1, & \text{if } 0.25N \leq n \leq 75N \\ \frac{4n}{n-1}, & \text{if } 0.25N \leq n \\ \frac{4(n-N)}{n}, & \text{if } 0.75N \leq n \end{cases}$
Simple Square Integral (SSI)	$SSI = \sum_{i=1}^N x_i ^2$
Variance of EMG (VAR)	$VAR = \frac{1}{N-1} \sum_{i=1}^N x_i^2 - \bar{x}^2$
Root Mean Square (RMS)	$RMS = \sqrt{\frac{1}{N} \sum_{i=1}^N x_i^2}$
Waveform Length (WL)	$WL = \sum_{i=1}^N x_{i+1} - x_i $
Willison Amplitude (WAMP)	$WAMP = \sum_{i=1}^N x_{i+1} - x_i $ $f(x) = \begin{cases} 1, & \text{if } x \geq \text{threshold} \\ 0, & \text{otherwise} \end{cases}$
Log detector (LOG)	$LOG = e^{\frac{1}{2} \sum_{i=1}^N x_i }$
Slope Sign Change (SSC)	$SSC = \sum_{i=1}^N f(x_i - x_{i-1} \times x_i - x_{i+1})$ $f(x) = \begin{cases} 1, & \text{if } x \geq \text{threshold} \\ 0, & \text{otherwise} \end{cases}$
Zero crossing (ZC)	$ZC = \sum_{i=1}^{N-1} [\text{sign}(x_n \times x_{n+1}) \cap x_n - x_{n+1} \geq \text{threshold}]$ $\text{sign} = \begin{cases} 1, & \text{if } x \geq \text{threshold} \\ 0, & \text{otherwise} \end{cases}$
Multi-scale amplitude modulation - frequency modulation (AM-FM)	$f(k) = \sum_{m=1}^M a_m(k) \cos \theta_m(k)$ Here $n = 1, 2, \dots, M$ indexes the AM-FM components, a_n represents the n th instantaneous amplitude, and θ_n represents the n th instantaneous phase. Here, AM-FM components are extracted over a dyadic filter bank.

Datenanalyse:

• **"time-domain":**

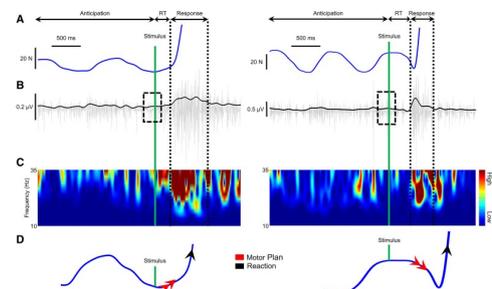
averaged rectified value, (ARV)

etc.

• **"frequency-domain":**

power spectrum median frequency, (MF)

- Fast Fourier Transformation
- Wavelet Analysis



Delmas S, Casamento-Moran A, Park SH, Yacoubi B, Christou EA. Motor planning perturbation: muscle activation and reaction time. J Neurophysiol. 2018 Oct 1;120(4):2059-2065

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Muscle

EMG SIGNAL

BEGINNING

MIDDLE

END

Muscle Fatigue Index

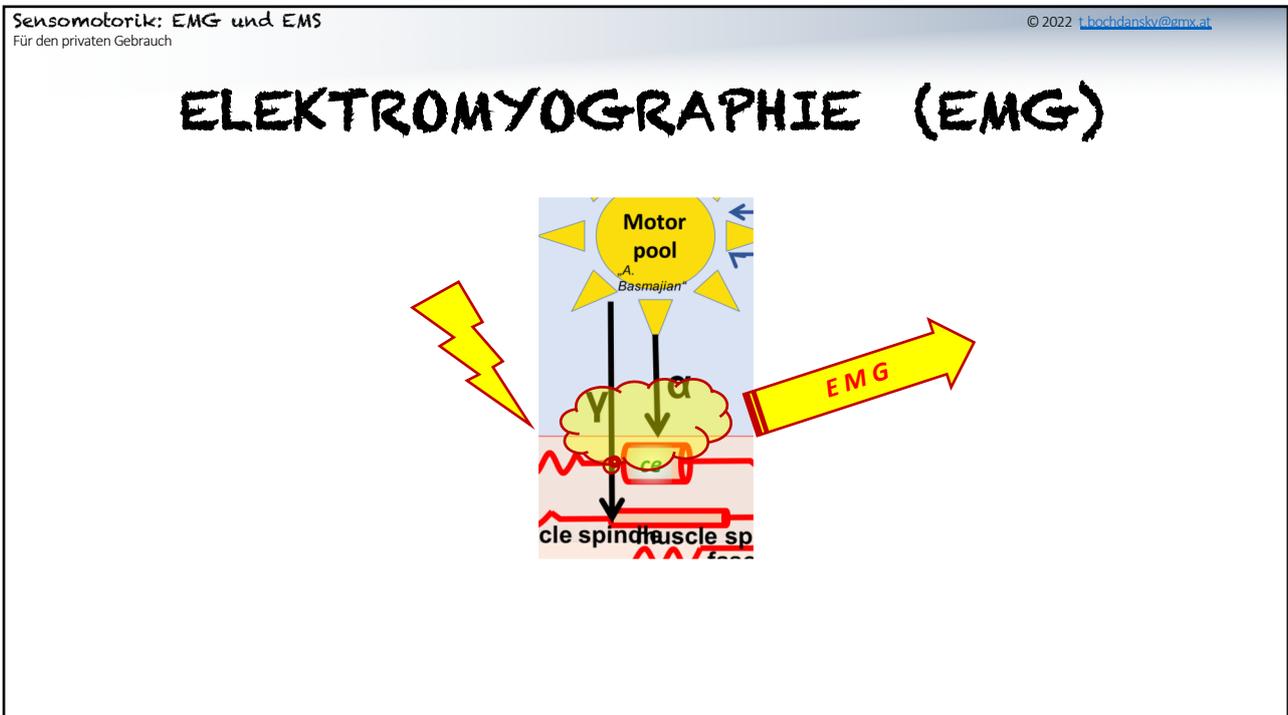
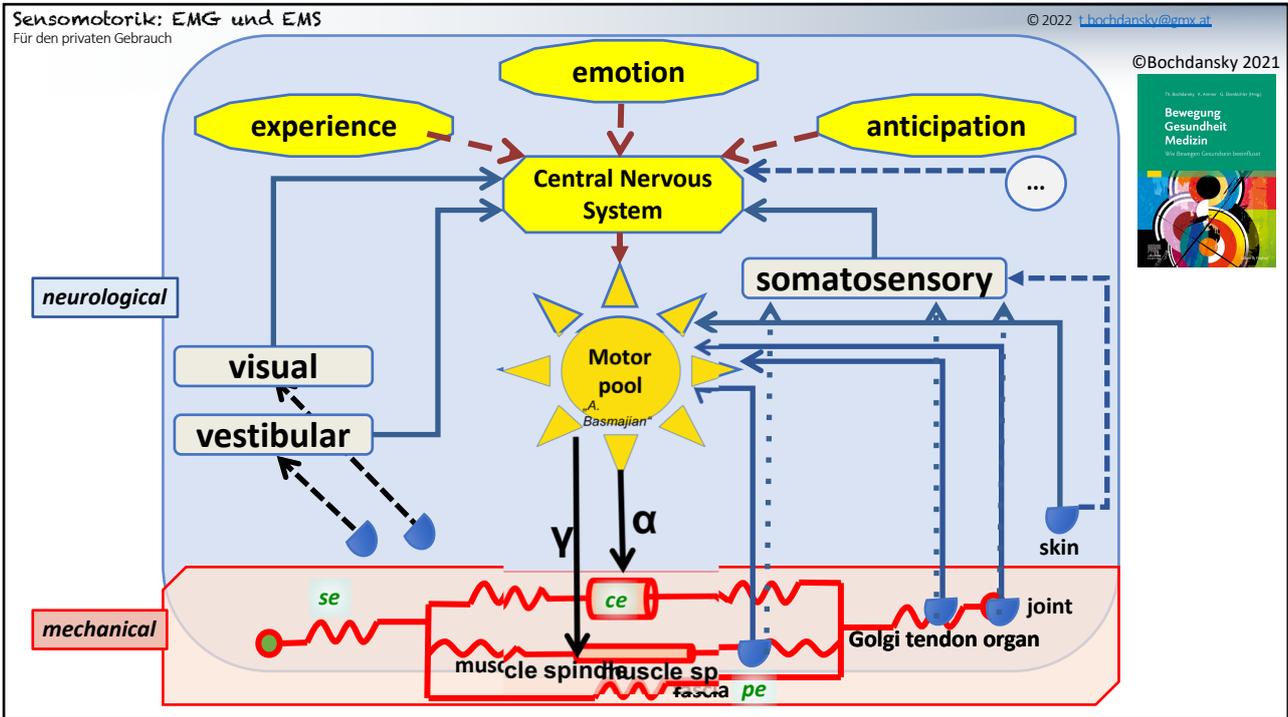
MUSCLE FATIGUE AND TIME-DEPENDENT PARAMETERS 217

Figure 8.4. The median frequency as a function of time for contractions performed at 20, 50, and 80% of the maximal voluntary contraction level in the first dorsal interosseus muscle.

Sensomotorik: EMG und EMS
Für den privaten Gebrauch

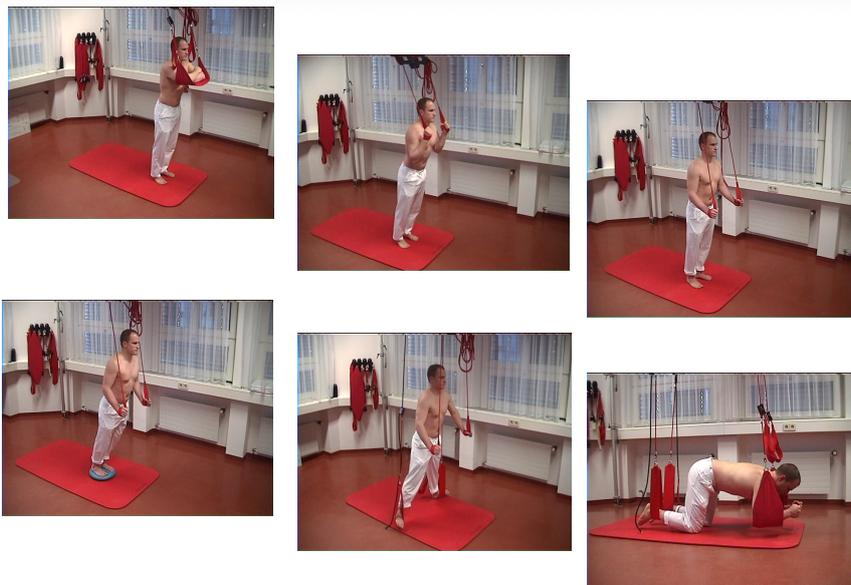
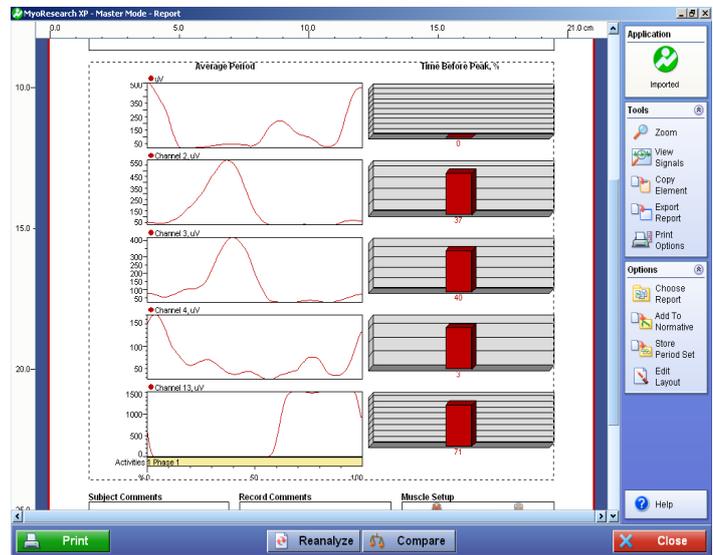
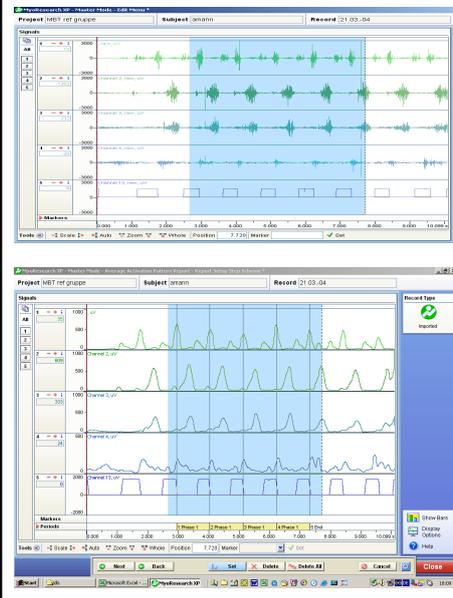
© 2022 l.bochdanskv@gmx.at

©Bochdanskv 2021

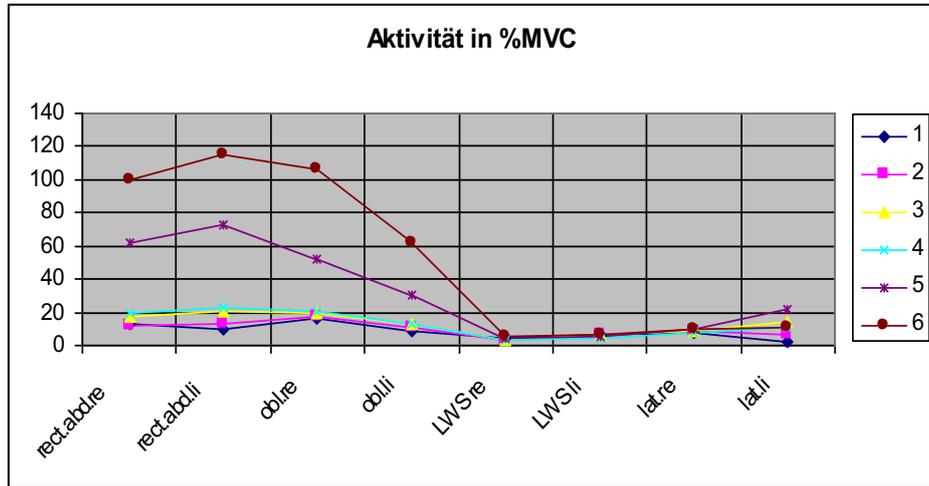


Beispiele

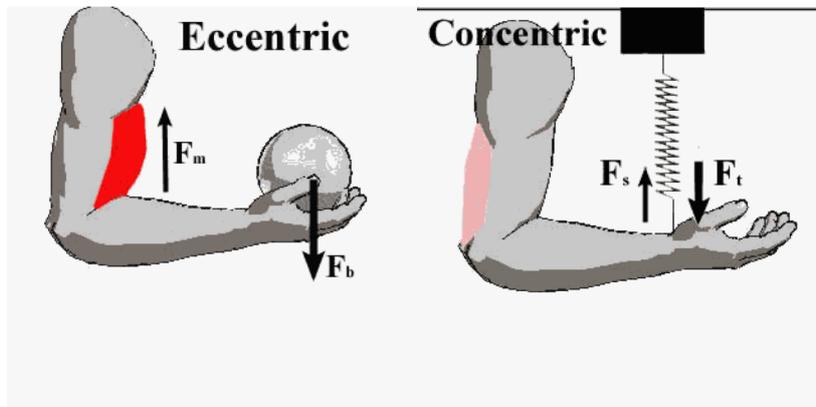
Ganganalyse



Übung 1 ... 6

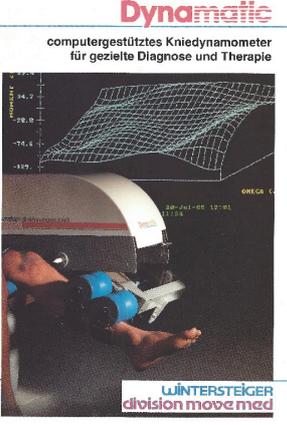


Komplementarität von Konzentrik und Exzentrik



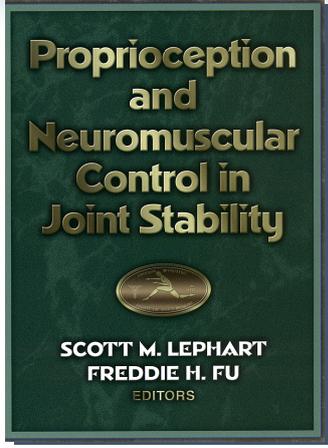
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Dynamie
computergestütztes Knie dynamometer
für gezielte Diagnose und Therapie

WINTERSTEIGER
division move.med



Proprioception and Neuromuscular Control in Joint Stability

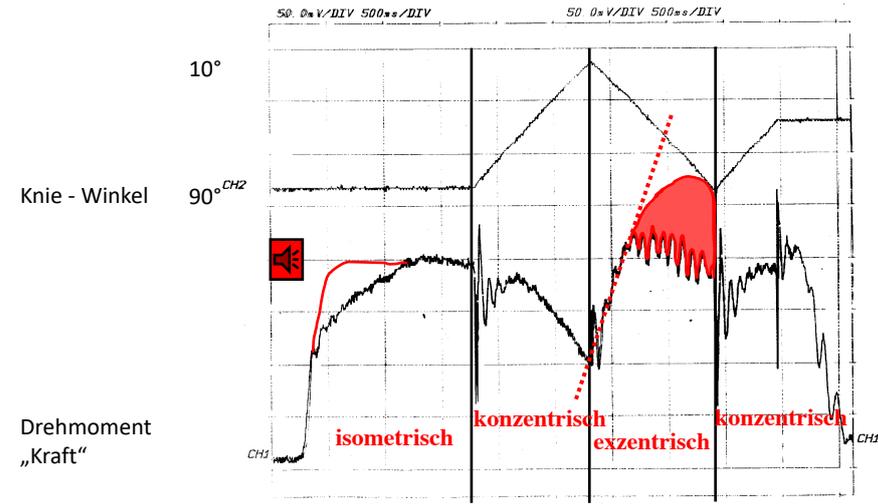
SCOTT M. LEPHART
FREDDIE H. FU
EDITORS

Bohdansky Th.,
Die dynamische Beurteilung der Muskelkraft bei konzentrischer und exzentrischer Muskelarbeit.
Österr.Zeitschrift Phys.Med, 4, Suppl. 1994

Bohdansky Th., Kollmitzer J., Ebenbichler G.:
The role of electromyography in the assessment of neuromuscular control.
In: Lephart S., Fu F.(ed): Proprioception and neuromuscular Control in joint stability. Human Kinetics,2000.

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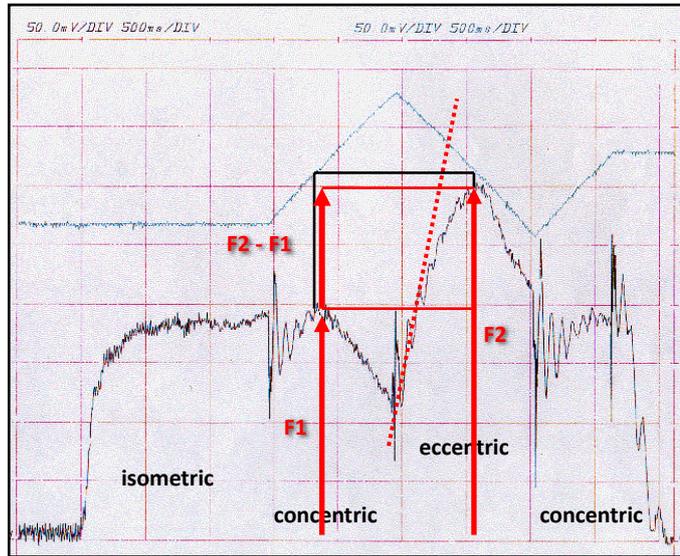
Knie - Winkel

Drehmoment „Kraft“

isometrisch konzentrisch exzentrisch konzentrisch

„isokinetisch“:
Konstante Bewegungsgeschwindigkeit

Dynamogramm am Ende des Tests (ca. 20 min)



F1: concentric force
F2: eccentric force

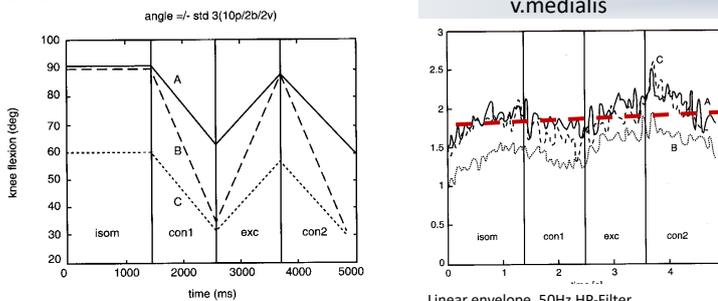
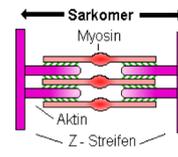


Figure 14.2 Mean angle position signals for trials A, B, and C calculated for 40 trials each ($SD = 2^\circ$).

Versuch C v.med isometriernormiert (n=10x4)

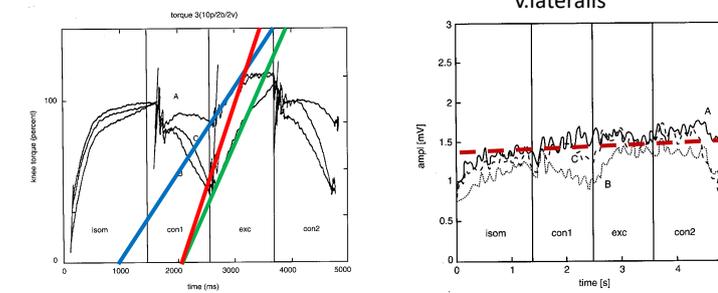
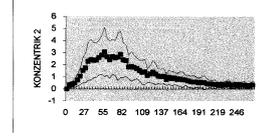
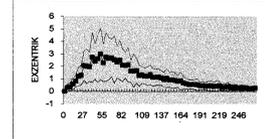
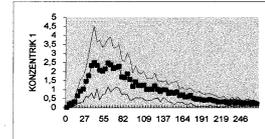
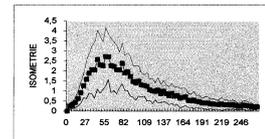
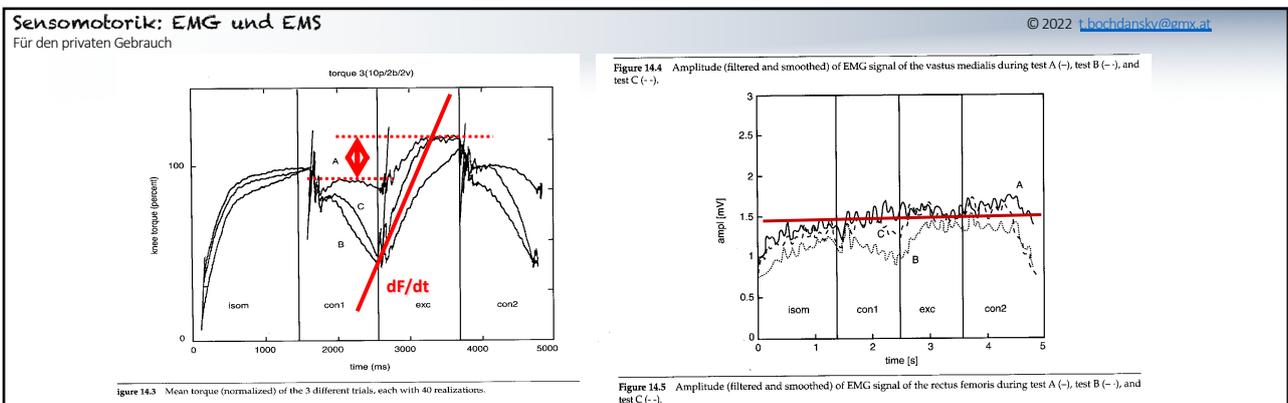
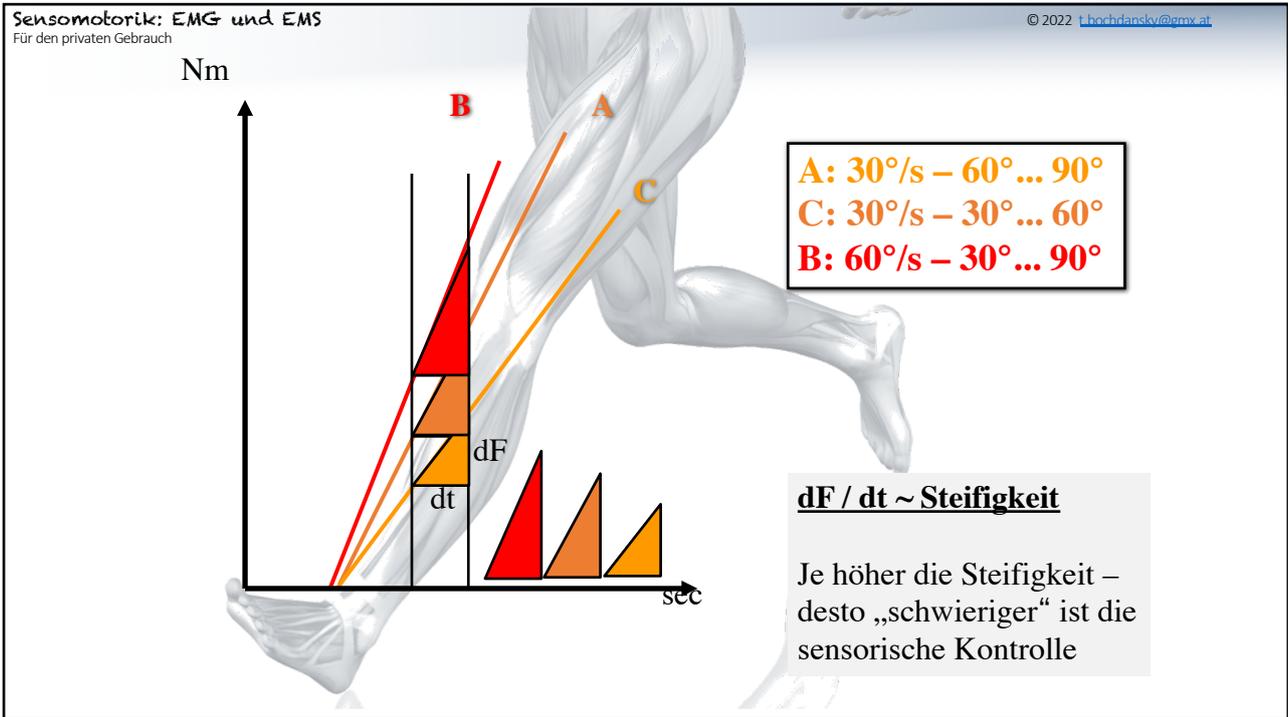


Figure 14.3 Mean torque (normalized) of the 3 different trials, each with 40 realizations.

test A (-),

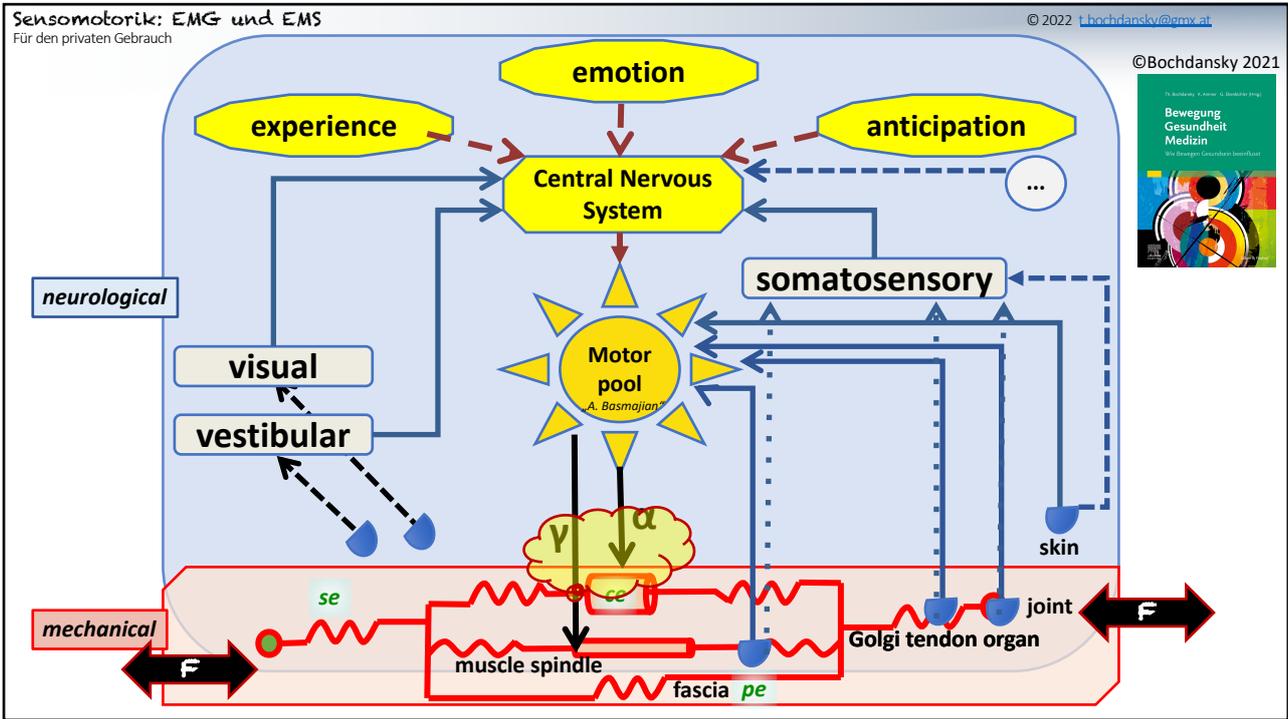
Amplitude (filtered and smoothed) of EMG signal of the rectus femoris during test A (-), test B (-), and



Exzentrische Belastung des Muskel – Sehnen – Apparat:

- Hohe mechanische Spannung
- Steiler Spannungsanstieg (dF/dt)
- Konstante alpha-Motorik

→ schwierige Bewegungskontrolle



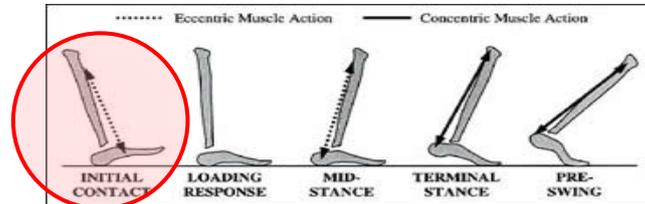
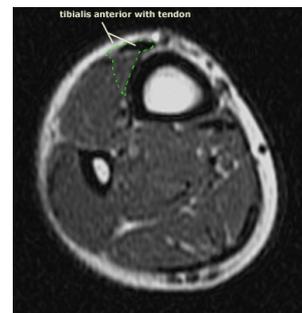


Figure 5.
Motion and net muscle action of the foot-ankle complex in walking gait.

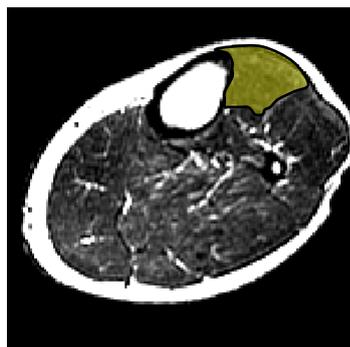
<http://www.rehab.research.va.gov/>

Exzentrische Muskelaktivität

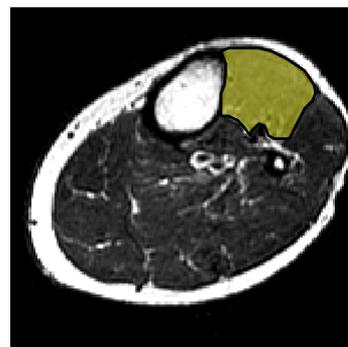
- Hohe mechanische Spannung
Hoher intramuskulärer Druck
- Hohe Anforderung an sensomotorische Kontrolle



vor dem Training



nach dem Training



m.tibialis anterior:
Hoher Druck → „shin splint syndrom“

Sensomotorik: EMG und EMS
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Shin splint syndrom: example marathon runner timing of m.tibialis ant.

12 km/h ohne Schmerzen vor TH

without pain, before therapy, after 2 minutes running

12 km/h mit Schmerzen vor TH

with pain, before therapy, after 20 minutes running

12 km/h nach TH

without pain, after therapy, after 20 minutes running

EMG: surface EMG, average 12 steps, foot switches Treadmill (woodway), running with 12km/h

Acknowledgements: E.B. Zwick, J. Kollmitzer

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... after 20 min running: pain

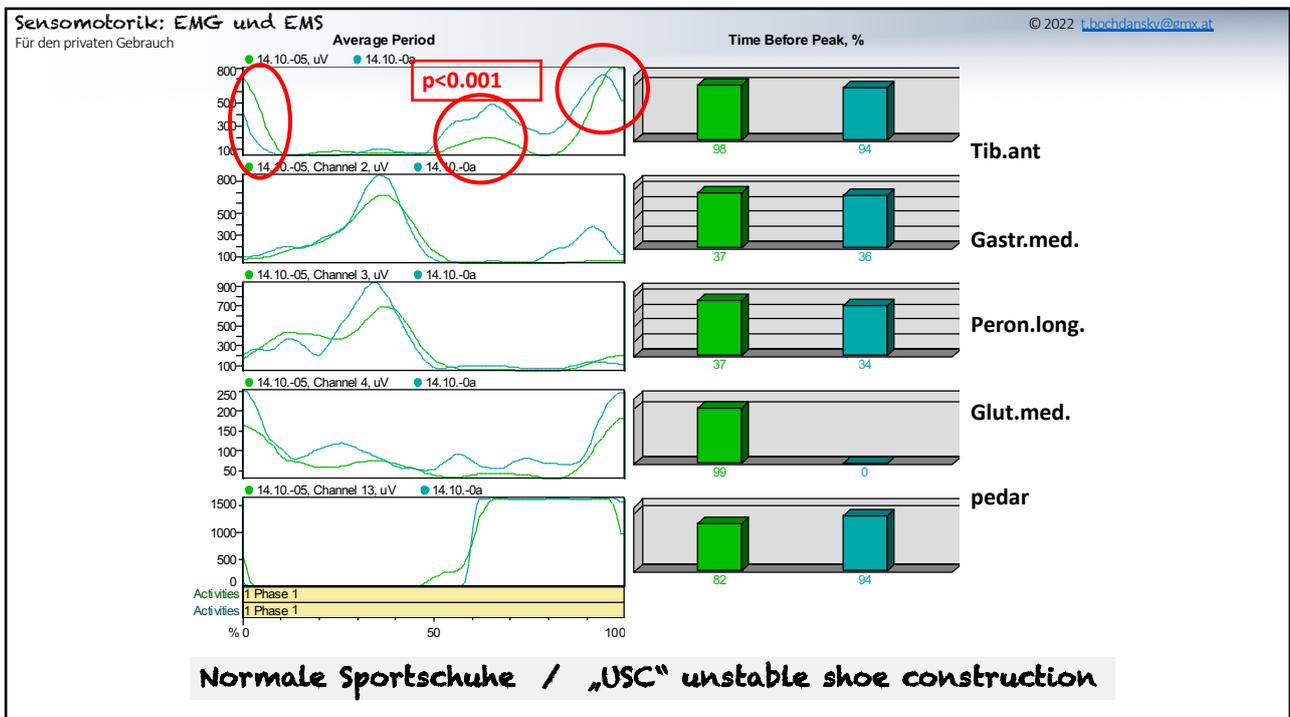
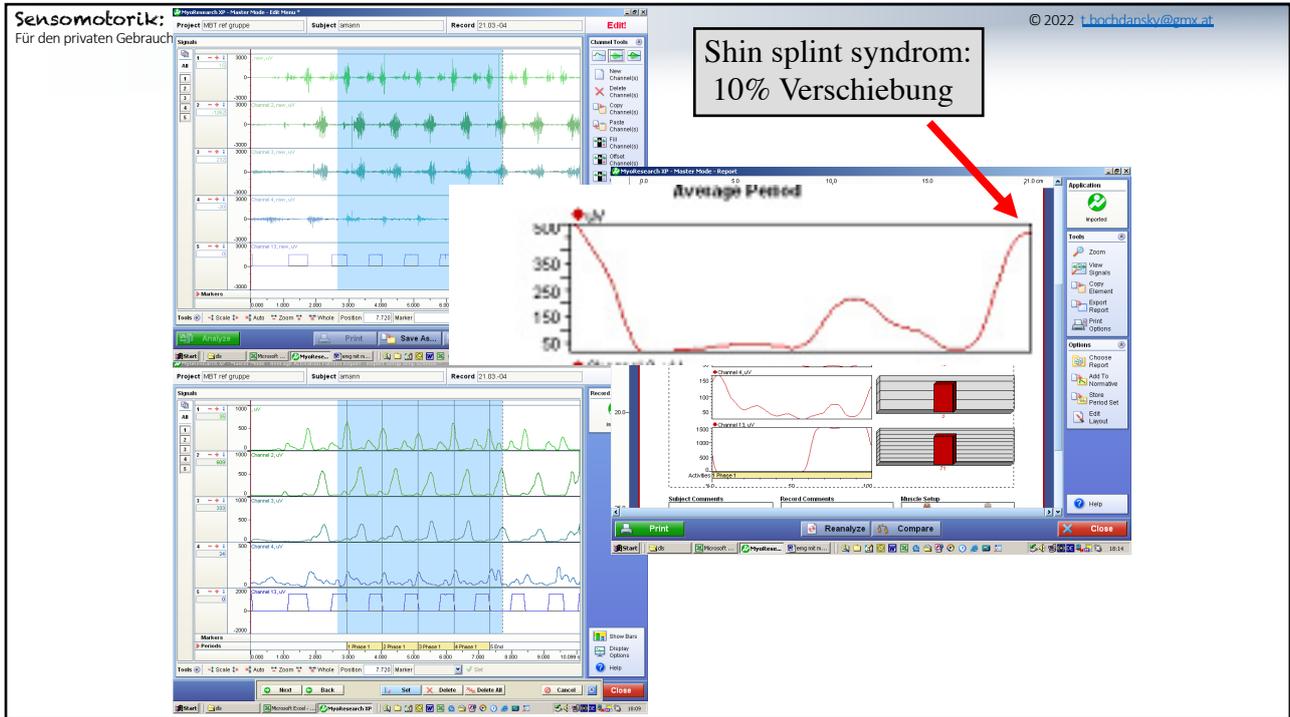
12 km/h ohne Schmerzen vor TH

~ 10% gait cycle

arbitrary units

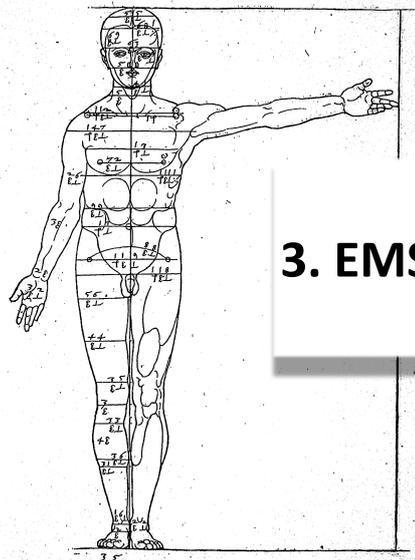
100 % Bewegungszyklus

Toe Off



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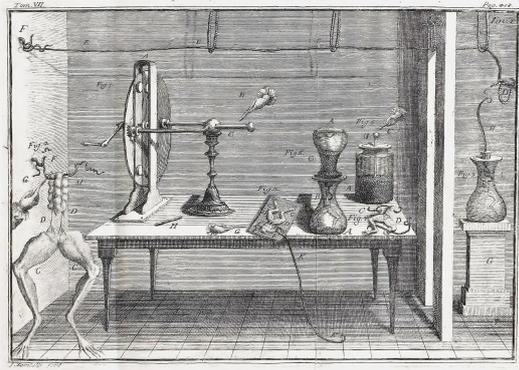
3. EMS

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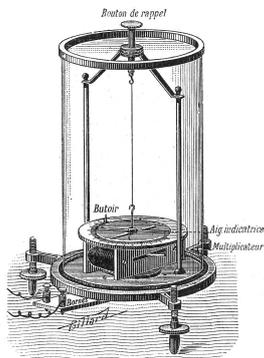
HISTORY:

Luigi GALVANI: 1737 – 1798
„De viribus electricitatis in motu musculari“ (1791)



Carlo Matteucci (1811 – 1868)
Trattato dei fenomeni elettrofisiologici degli animali. 1844.

empfindlichen Galvanometer von **Leopoldo Nobili** (1784 – 1835)



https://hr.wikipedia.org/wiki/Leopoldo_Nobili#/media/Datoteka:Galvanometre_de_Nobili.jpg

astatic galvanometer, invented by Leopoldo Nobili in 1825

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HISTORY:

„Gegen beide Arten Podagra (Gichtanfall im Großzehengrundgelenk, "Zipperlein"), muss man einen lebenden schwarzen Zitterrochen wenn der Schmerz naht unter die Füße legen, stehend nicht an einem trockenen Gestade, sondern an einem solchen, welches das Meer bespült, bis man merkt, dass der ganze Fuß und das Schienbein bis zu den Knien betäubt ist. Dies Mittel beseitigt sowohl für den Augenblick die Schmerzen als heilt auch für die Zukunft. Dadurch ist Anteros, der Freigelassene des Tiberius, der Prokurator der Erbschaften, geheilt worden.“
Scribonius Largus 46 v.Chr.

Die
Electrische Medicin
oder die
Kraft und Wirkung
der
Electricität
in dem
menschlichen Körper und dessen Krankheiten
besonders
bey gelähmten Gliedern
aus Vernunftgründen erläutert und durch Erfahrungen bestätiget
von
Johann Gottlieb Schäffer,
der Weltweisheit und Naturgeschichte Doctor, der Kaiserl. Academie der Naturforscher und der Ehrentz. Bayerischen Academie zu München ordentlichem Mitgliede, und practischem Arzte zu Regensburg.
Regensburg, verlegt Johann Leopold Neumann. 1766.

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**Guillaume Benjamin Amand
Duchenne de Boulogne**
1806 - 1875

Kurz A, Volk GF, Arnold D, Schneider-Stickler B, **Mayr W**, Guntinas-Lichius O.
Selective Electrical Surface Stimulation to Support Functional Recovery in the Early Phase After Unilateral Acute Facial Nerve or Vocal Fold Paralysis.
Front Neurol. 2022 Apr 4;13:869900.

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Finzi E, Rosenthal NE.
Emotional proprioception: Treatment of depression with afferent facial feedback.
J Psychiatr Res. 2016 Sep;80:93-96.

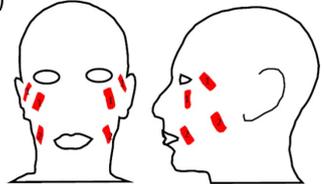
The circuitry involved in this latter effect is a logical target for treatment with botulinum toxin, and we review the evidence in support of this strategy.

Soundirarajan M, Kuca K, Krejcar O, Namazi H.
Decoding of the **coupling between the brain and facial muscle reactions in auditory stimulation.**
Technol Health Care. 2022;30(4):859-868.

Rock music has a greater effect on the information of EEG and EMG signals than pop music, which itself has a greater effect than relaxing music. Furthermore, a strong correlation ($r=0.9980$) was found between the variations of the information of EEG and EMG signals.
The **activities of the facial muscle and brain are correlated** in different conditions.

Kapadia N, Zivanovic V, Moineau B, Downar J, Zariffa J, Popovic MR.
Functional electrical stimulation of the facial muscles to improve symptoms in individuals with major depressive disorder: pilot feasibility study.
Biomed Eng Online. 2019 Nov 14;18(1):109.

facial FEST is an **acceptable, practical, and safe treatment in individuals with MDD.**
We provide preliminary evidence to show improvements in depressive symptoms following a minimum of 10 FEST sessions.
Each FEST session lasted 1 h, which included donning and doffing the electrodes (~ 15 min) and consisted of alternating periods of stimulation and rest, 15 s each. FEST was delivered using Compex Motion stimulator (Compex SA, Switzerland)



Sensomotorik: EMG und EMS
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Schädelgalvanisation

Kowarschick, 1920

ELEKTROTHERAPIE

EIN LEHRBUCH
VON
DR. JOSEF KOWARSCHIK
PROFESSOR AN DER UNIVERSITÄT ZÜRICH
HISTORISCHES INSTITUT FÜR ANATOMIE UND PHYSIOLOGIE

MIT 256 ABBILDUNGEN
UND 5 TAFELN

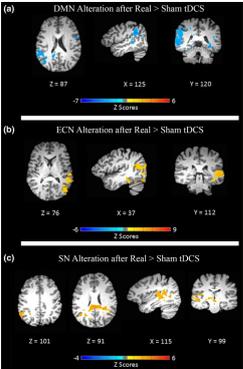


SPRINGER-VERLAG BERLIN HEIDELBERG GMBH
1920

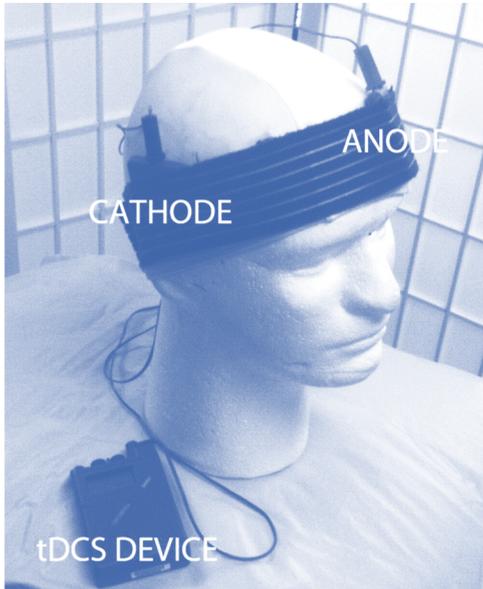


Shahbaba A, Ebrahimipour M, Hariri A, Nitsche MA, Hatami J, Fatemizadeh E, Oghabian MA, Ekhtiari H.
Transcranial DC stimulation modifies functional connectivity of large-scale brain networks in abstinent methamphetamine users.
Brain Behav. 2018 Feb 15;8(3):e00922

Subjective **craving decreased significantly** after real tDCS compared to sham stimulation



TDCS: transcraniale – direct – current - stimulation

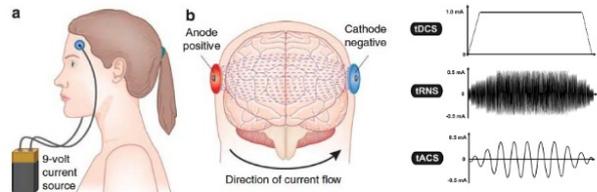


DIRECT CURRENT

The electrode placement and direction of current flow has specific effects (George 2010)

Anodal current = depolarizing

Cathodal current = hyperpolarizing



George MS, Aston-Jones G. Noninvasive techniques for probing neurocircuitry and treating illness: VNS, TMS, and tDCS. *Neuropsychopharmacology* 2010; 35: 301-316. Saete C, Tur Z, Paulus W, Arsal A. Combining functional magnetic resonance imaging with tDCS. *Front Hum Neurosci* 2013; 7: 439; 1-7.



Beispiele aktueller Publikationen (pubmed in Summe > 6.000)

Veldema J, Gharabaghi A.
Non-invasive [brain stimulation for improving gait](#), balance, and lower limbs motor function in stroke. *J Neuroeng Rehabil.* [2022 Aug](#) 3;19(1):84.

Review: The data indicates that non-invasive brain stimulation/spinal cord **stimulation is effective in supporting recovery.**

Brak IV, Filimonova E, Zakhariya O, Khasanov R, Stepanyan I. [Transcranial Current Stimulation](#) as a Tool of Neuromodulation of [Cognitive Functions in Parkinson's Disease](#). *Front Neurosci.* [2022 Jul](#) 12;16:781488.

Based on the facts presented in this paper, it is possible to suggest the **potential effectiveness of mild cognitive impairment (MCI) correction by stimulating** the areas of the brain responsible for these disorders,

Ponce GV, Klaus J, Schutter DJLG.
A Brief History of [Cerebellar Neurostimulation](#). *Cerebellum.* [2022 Aug](#);21(4):715-730.

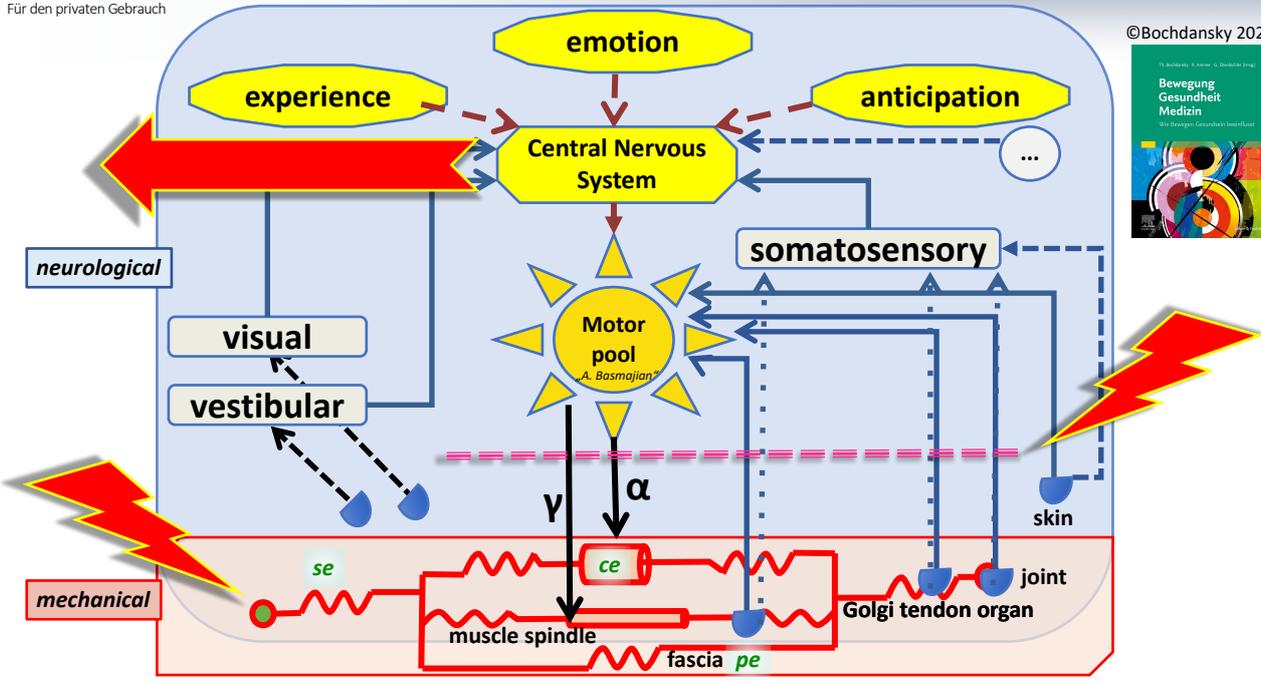
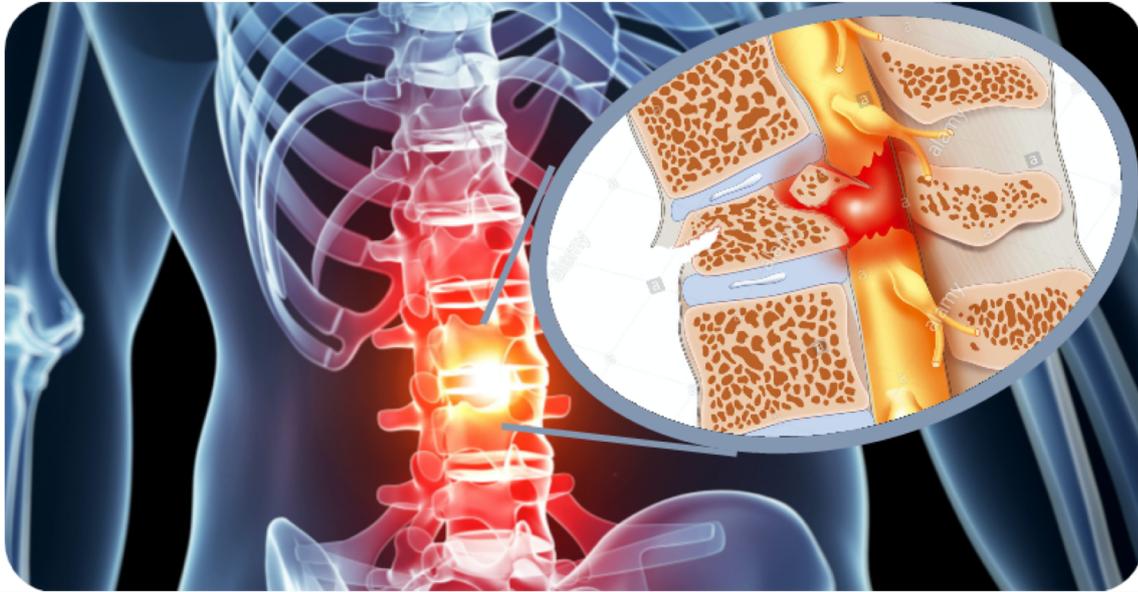
Klaus J, Schutter DJLG.
Non-invasive Brain [Stimulation of the Cerebellum in Emotion](#). *Adv Exp Med Biol.* 2022;1378:109-121.

Non-invasive stimulation of the cerebellum provides a unique experimental approach to study the relation between the **cerebellum and emotions** in humans.

Chang S. The [Application of Transcranial Electrical Stimulation in Sports Psychology](#). *Comput Math Methods Med.* 2022 Jul 13;2022:1008346.

transcranial direct current stimulation, transcranial alternating current stimulation, and transcranial random noise stimulation; influencing the **psychological fatigue of climbers**

SPINAL CORD INJURY



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Beaumont E, Guevara E, Dubeau S, Lesage F, Nagai M, Popovic M.
Functional electrical stimulation post-spinal cord injury improves locomotion and increases afferent input into the central nervous system in rats.
J Spinal Cord Med. 2014 Jan;37(1):93-100.

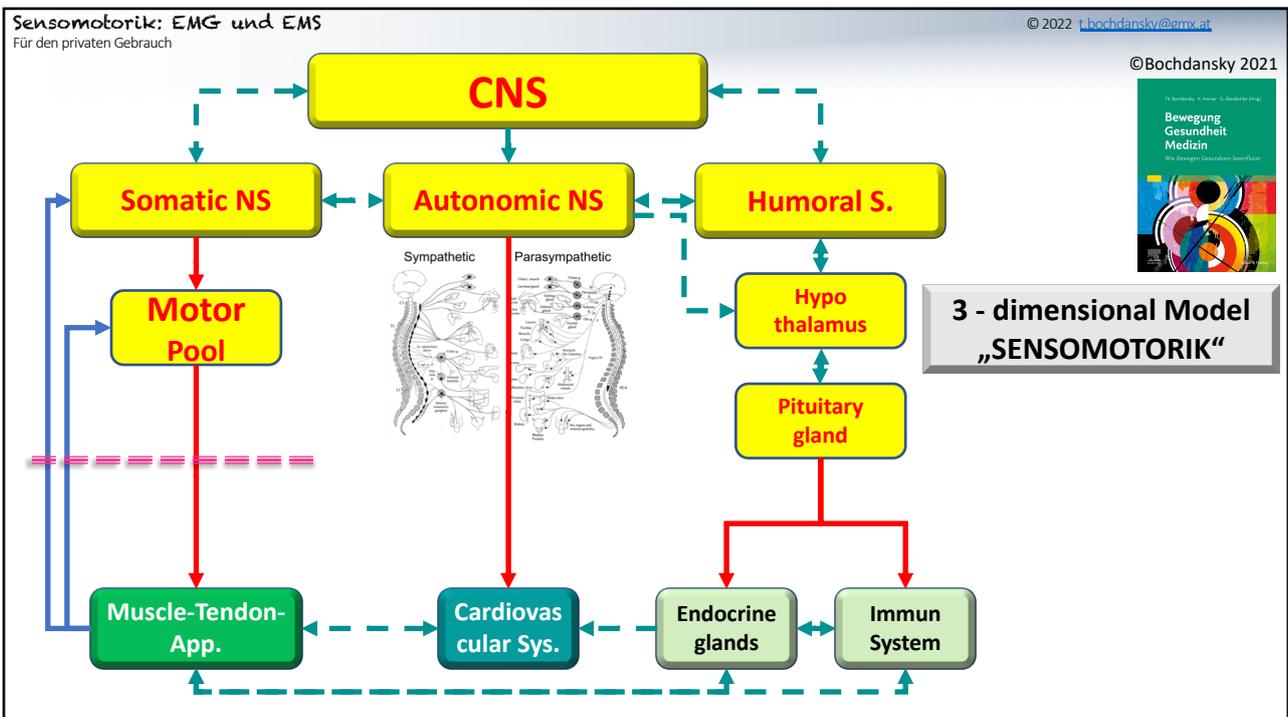
The results of this study indicate that **after FES, the CNS preserves/acquires the capacity to respond to peripheral electrical stimulation**

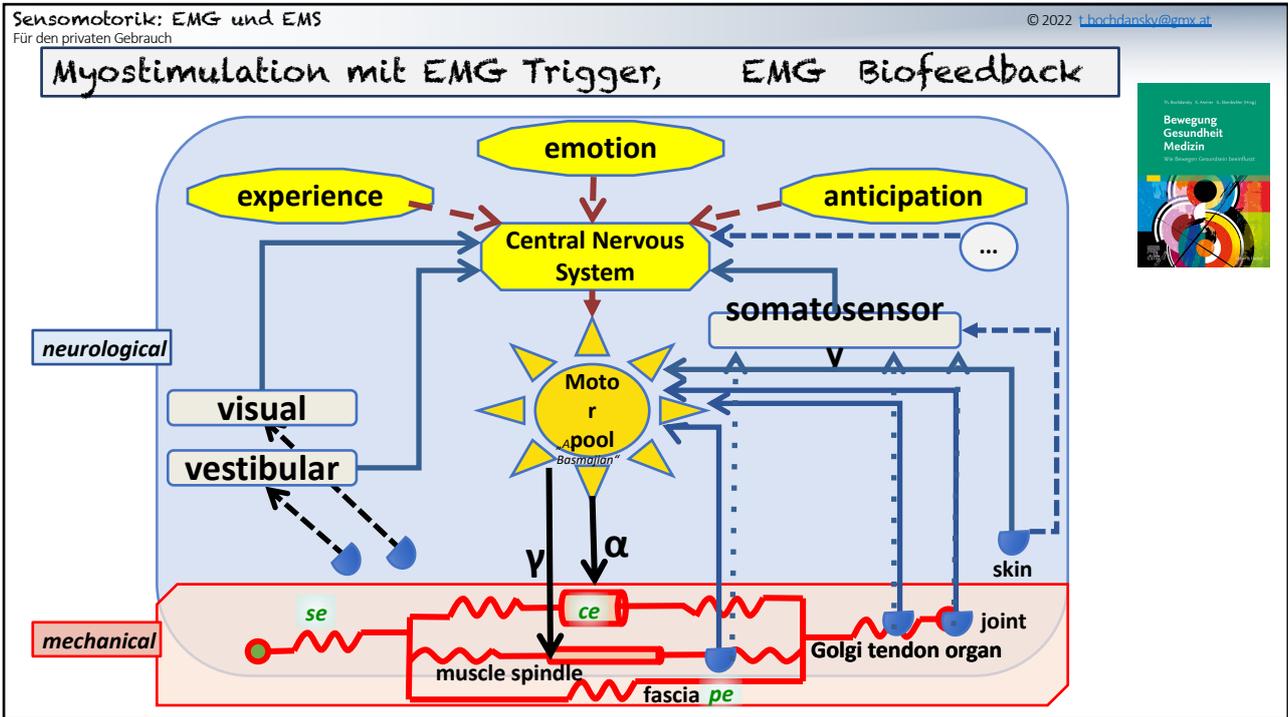
Dolbow DR, Gorgey AS, Sutor TW, Bochkezanian V, Musselman K.
Invasive and Non-Invasive Approaches of Electrical Stimulation to Improve Physical Functioning after Spinal Cord Injury.
J Clin Med. 2021 Nov 17;10(22):5356.

The routine uses of **FES/NMES in combination** with other therapies, such as standing frames and treadmill training, could maximize muscle health, aerobic fitness, and cardiometabolic outcomes. Whether it be through NMES, FES cycling, or task-specific movement training enhanced by epidural electrical stimulation, the benefits of using invasive and non-invasive electrical stimulation for targeting function have the potential to **enhance functional mobility and increase the quality of life** of people with SCI.

Siu R, Brown EH, Mesbah S, Gonnelli F, Pisolkar T, Edgerton VR, Ovechkin AV, Gerasimenko YP.
Novel Noninvasive Spinal Neuromodulation Strategy Facilitates Recovery of Stepping after Motor Complete Paraplegia.
J Clin Med. 2022 Jun 25;11(13):3670.

locomotor training with multi-segmental spinal cord transcutaneous electrical stimulation (scTS).
important role of afferent feedback in further improvement of voluntary control and reorganization of the sensory-motor brain-spinal connectome.





Sensomotorik: EMG und EMS
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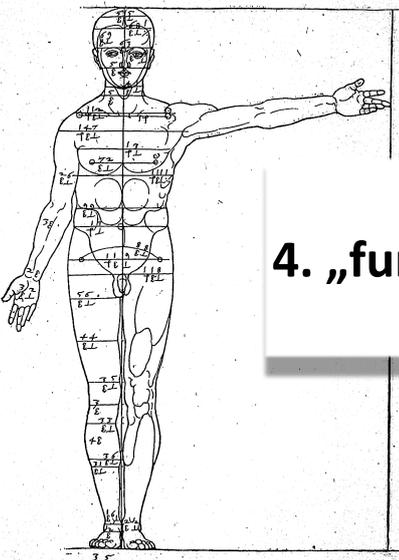
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EMS : Elektro-myo-stimulation
wird im Sport eingesetzt, um die muskuläre Leistungsfähigkeit zu steigern und den systematischen Trainingsprozess zu unterstützen

The image illustrates the application of EMS in a gym. It features a **BODY STREET** EMS control panel with multiple adjustment knobs and buttons. Below the panel, a person is shown in a gym environment, receiving assistance from another person. A close-up view of the EMS electrode pads is also provided.

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4. „funktionelle“ Stimulation

Sensomotorik: EMG und EMS
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„funktionell“

Duden:

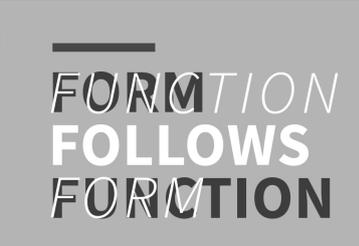
- die Funktion (1c) erfüllend, im Sinne der Funktion wirksam; das Funktionieren, die Funktionen betreffend, eine bestimmte Funktion habend
- die Leistungsfähigkeit des Organs betreffend; mit der normalen bzw. gestörten Funktion eines Organs zusammenhängend

Oxford languages:

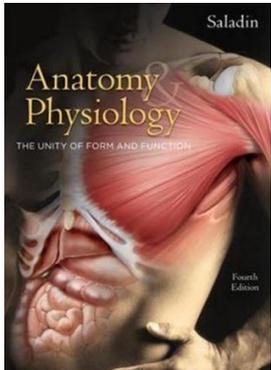
- dem Zweck entsprechend
- auf das richtige Funktionieren bezogen

Funktion:
Beschreibt den Zusammenhang zwischen Größen / Mengen bzw die Aufgabe innerhalb eines Systems

Struktur:
Beschreibt die Gesamtheit und Wechselwirkungen der Elemente eines Systems

Louis Sullivan: The tall office building artistically considered, 1896.



Sensomotorik: EMG und EMS
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„funktionelle“ elektrische Stimulation:

Beschreibung der Aufgaben der Elektrostimulation innerhalb des „SMS“

„functional stimulation“ Pubmed (August 2022): ca. 1.200.000 results
 „functional electrical stimulation“ Pubmed (August 2022): ca. 160.000 results

Sawa K, Amimoto K, Meidian AC, Ishigami K, Miyamoto T, Setoyama C, Suzuki R, Tamura M, Miyagami M.
[Efficacy of sitting balance training with delayed visual feedback among patients with stroke: a randomized crossover clinical trial.](#)
 J Phys Ther Sci. **2022 Aug**;34(8):540-546.

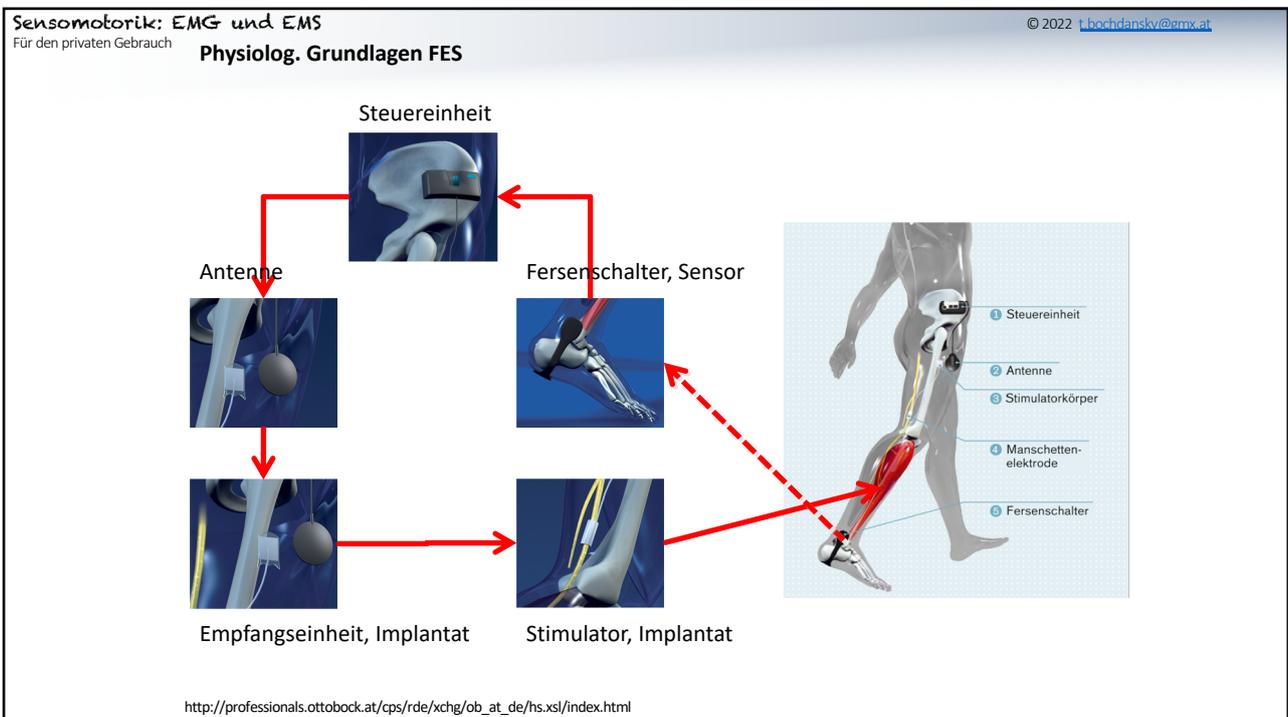
Sensory-motor feedback to visual stimulation can improve postural control, balance, and activities of daily living.

Cavalcante JGT, de Almeida Ventura Á, de Jesus Ferreira LG, de Sousa AMM, de Sousa Neto IV, de Cássia Marqueti R, Babault N, Durigan JLQ.
[Hip and Knee Joint Angles Determine Fatigue Onset during Quadriceps Neuromuscular Electrical Stimulation.](#)
 Appl Bionics Biomech. **2022 Jul 22**;2022:4612867.

QF NMES-induced contraction fatigability is greater when the knee is flexed at 60° compared to 20°. In addition, a supine position promotes earlier fatigue for a 60° knee flexion, but it delays fatigue onset for a 20° knee flexion compared to the seated position.

RESULTS BY YEAR

1889 2023



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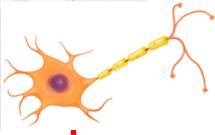
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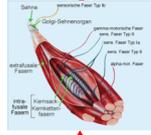
Steuereinheit



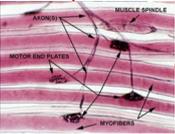
Antenne



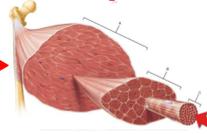
Sensor

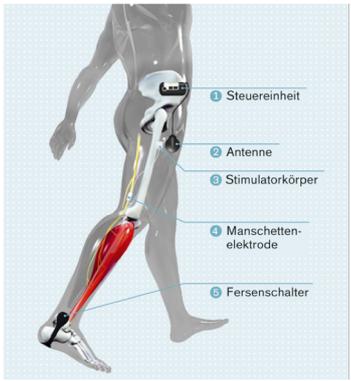


Empfangseinheit



Stimulator





- 1 Steuereinheit
- 2 Antenne
- 3 Stimulorkörper
- 4 Manschetten-elektrode
- 5 Fersenschalter

http://professionals.ottobock.at/cps/rde/xchg/ob_at_de/hs.xsl/index.html

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http://www.bioness.com/Healthcare_Professionals.php

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BCI-gesteuerte Neuroprothese: Patienten mit hoher Querschnittlähmung können mithilfe des BCI gekoppelt mit einer nicht-invasiven funktionellen Elektrostimulation einen Gegenstand ergreifen, © Forschungsjournal 2008/12 / TU Graz/ISD

<http://www.tobi-project.org/welcome-tobi>

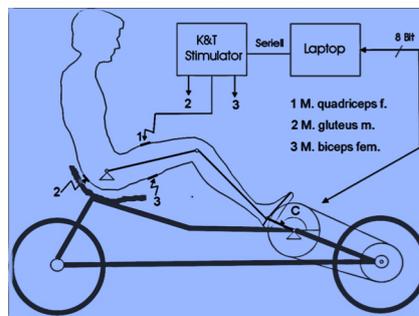
„Funktionelle“ Elektrostimulation



MEDEL, Stiwell



Otto Bock



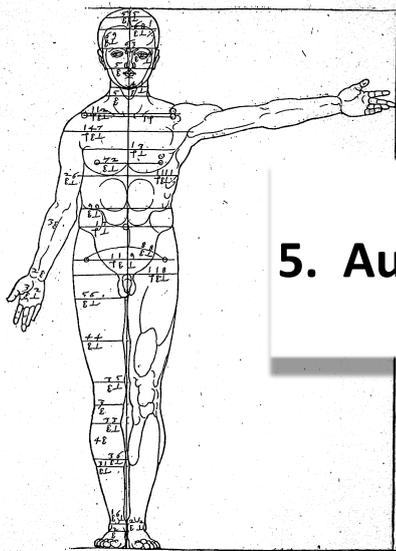
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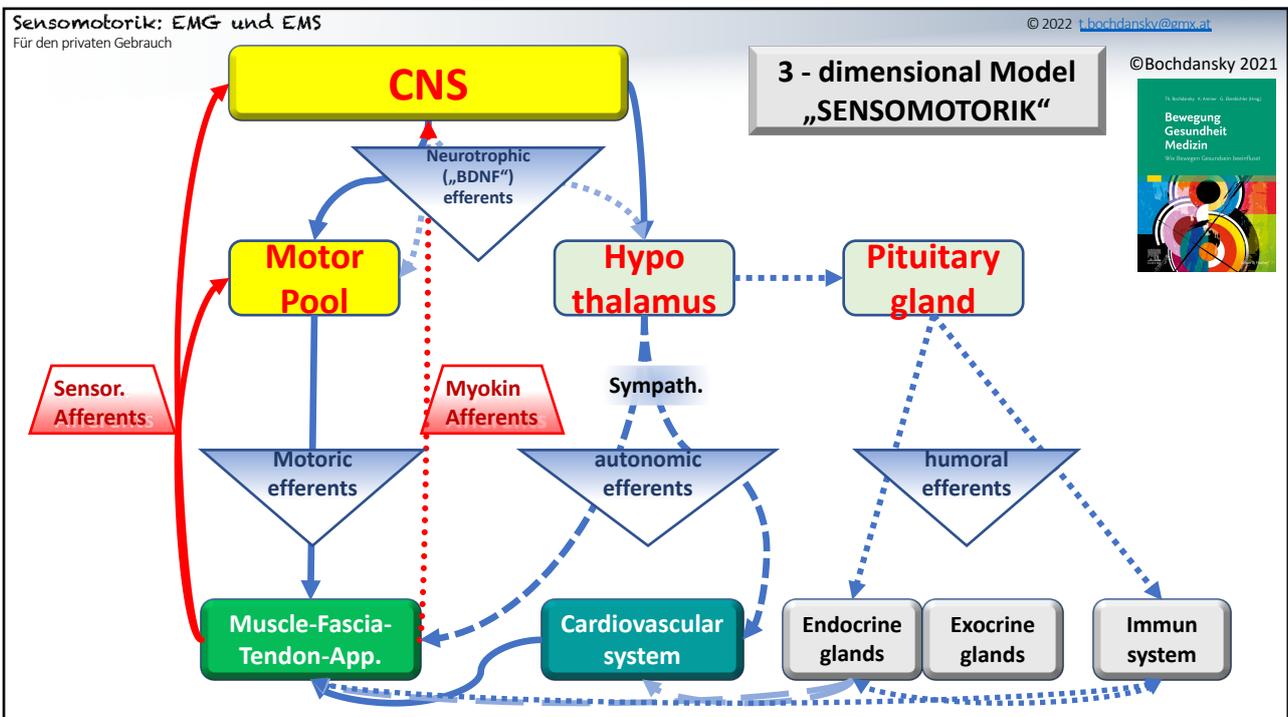
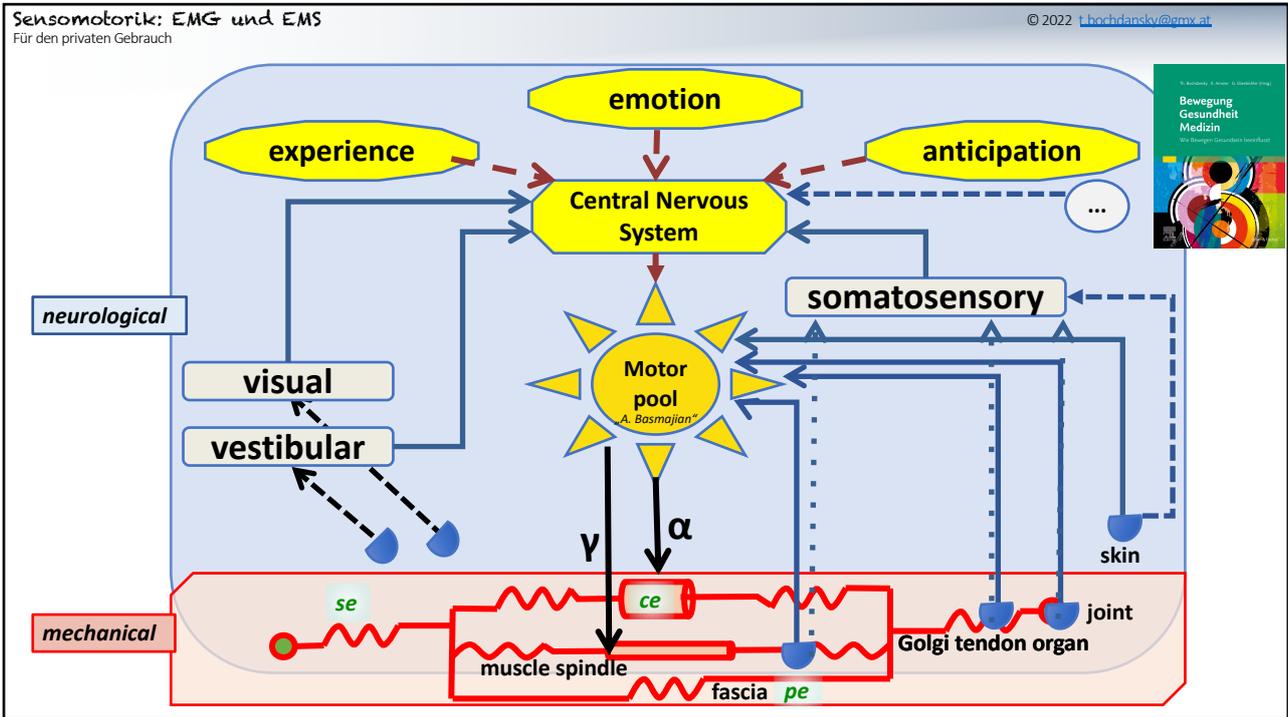


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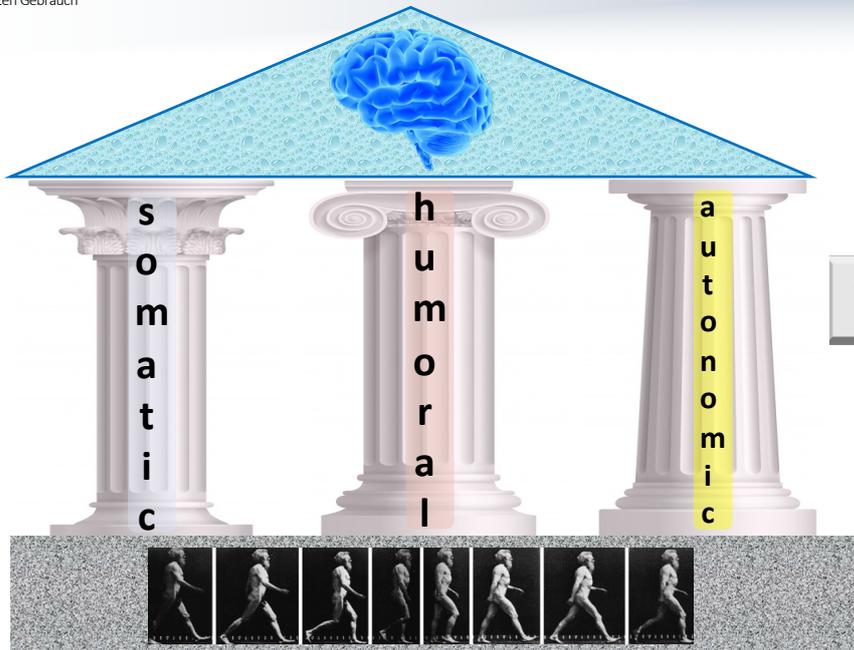
5. Ausblicke



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3 - dimensional Model
„SENSOMOTORIK“