ENGG1000

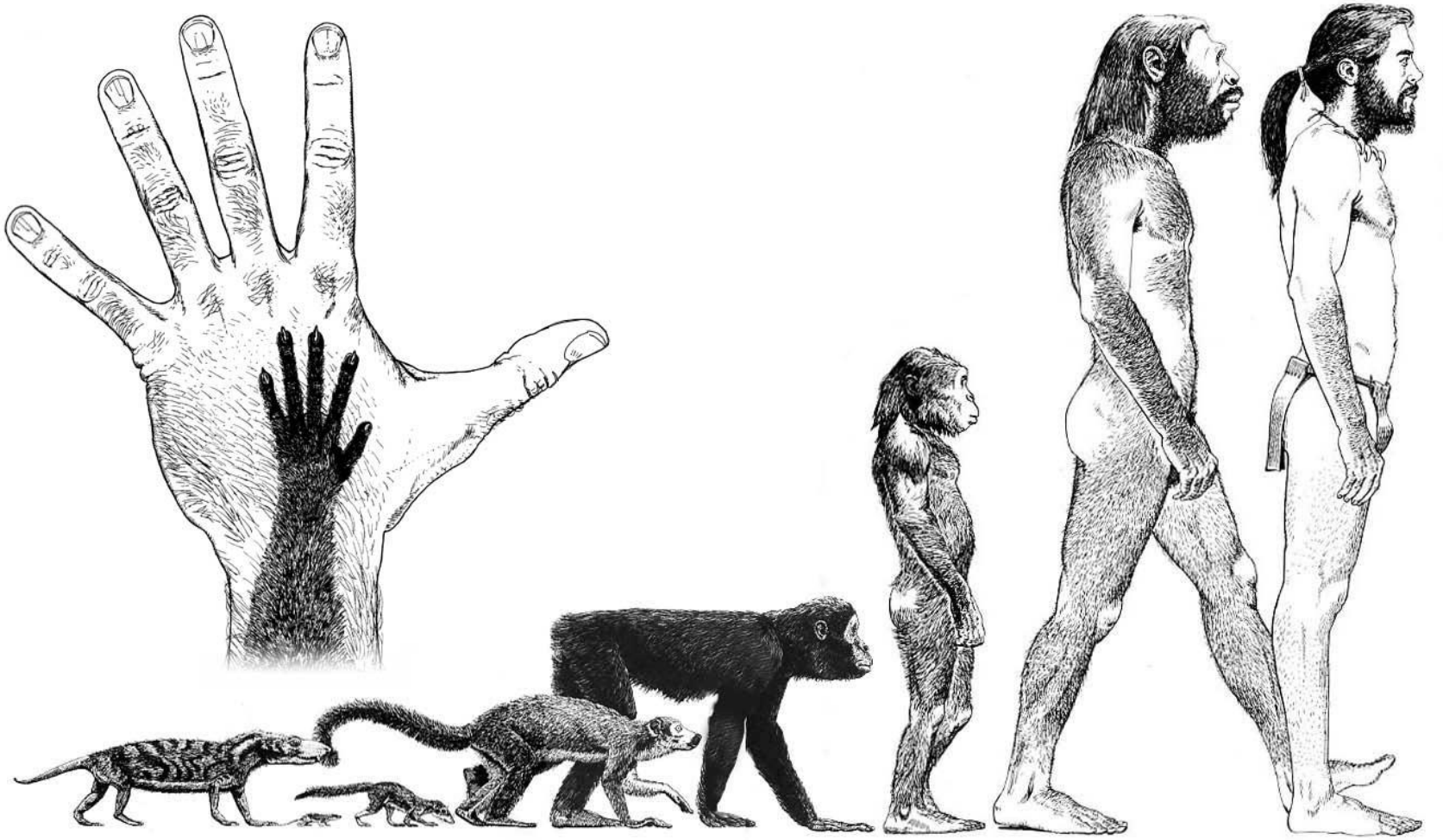
Lecture (22-March-2018)

Function of the hand

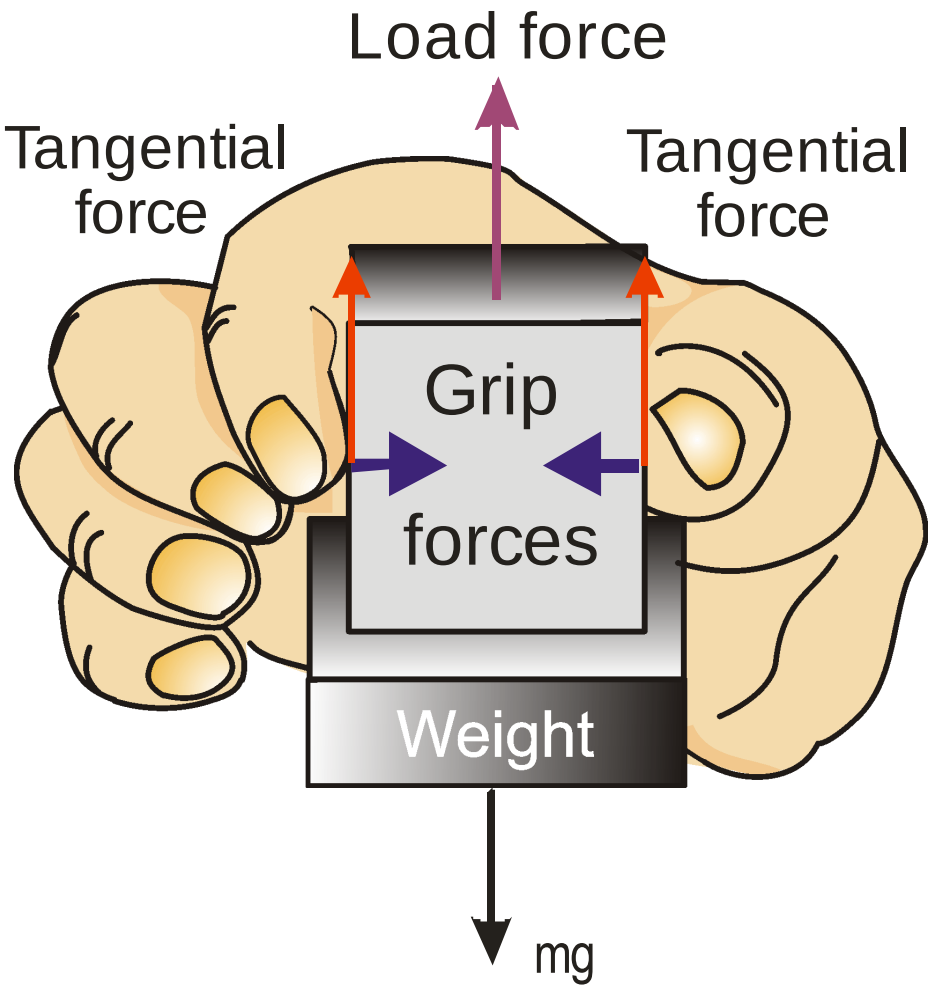
Dr Ingvars Birznieks
Autumn 2018

Versatility of the human hand

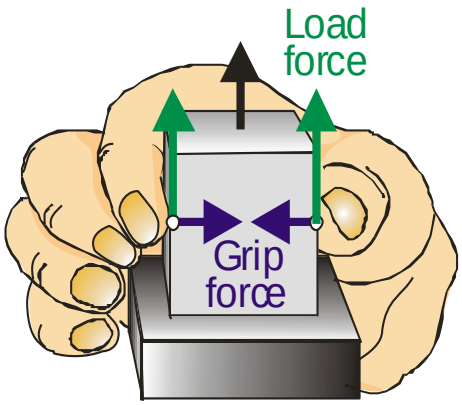
Ability to manipulate objects enabled us to become the dominant species on Earth

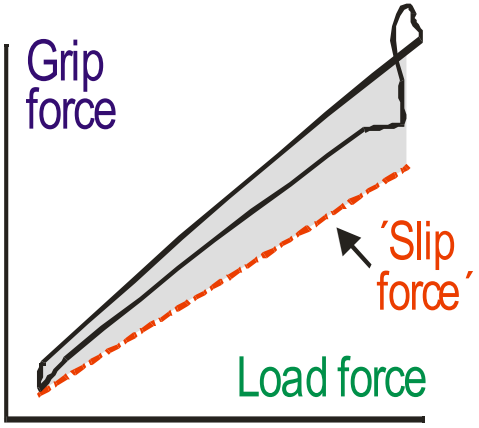


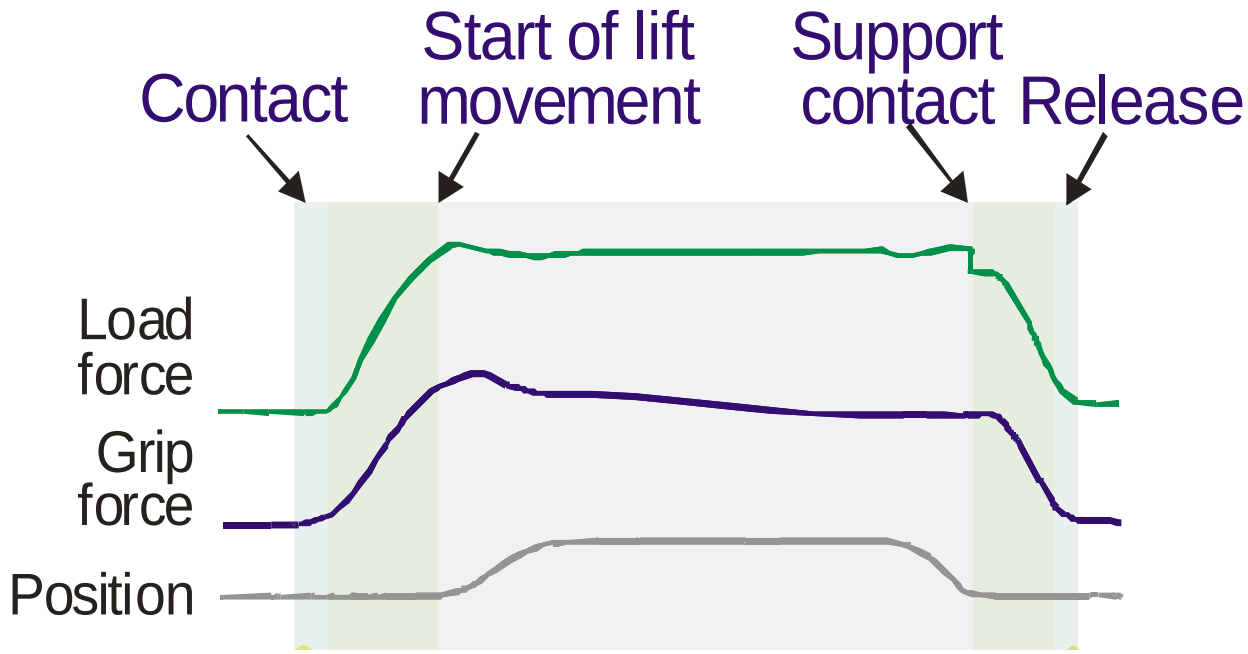
Control of fingertip forces during object manipulation



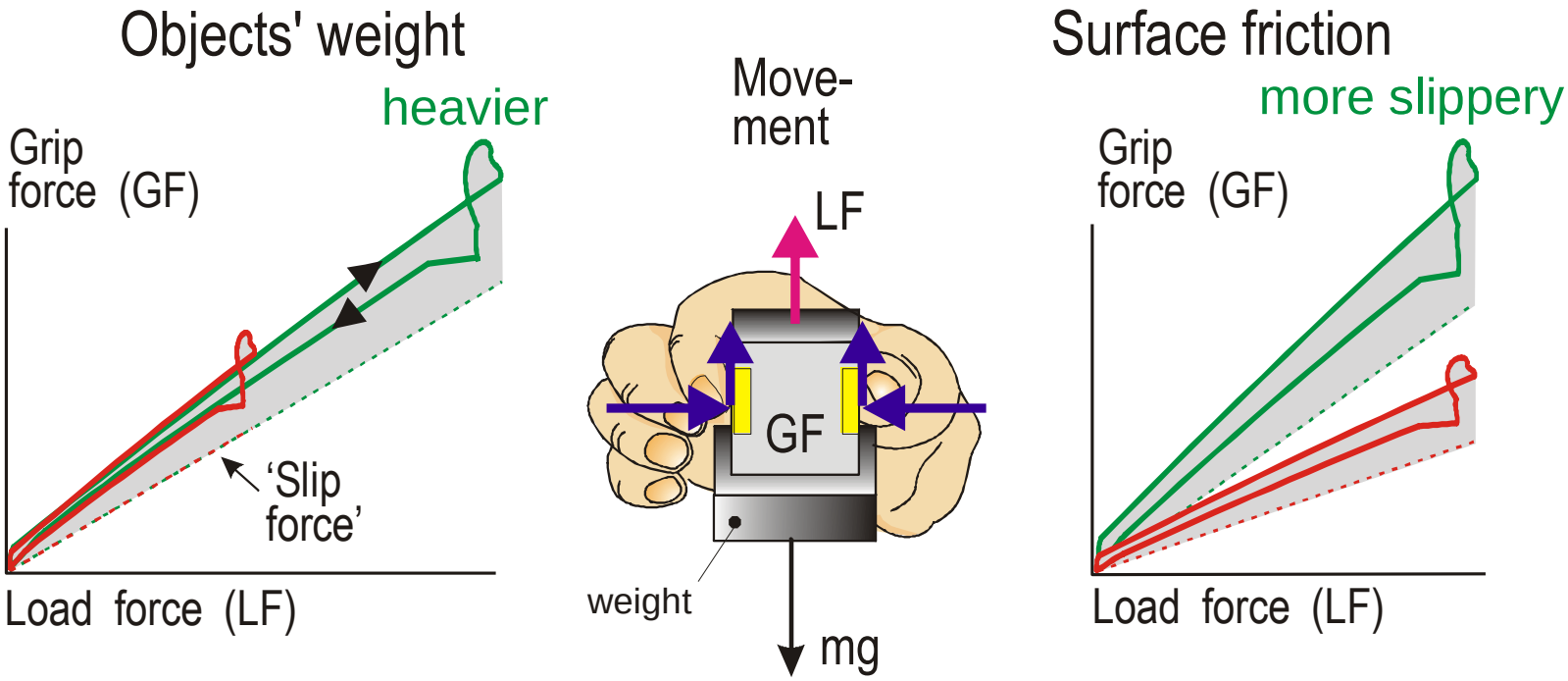
Control of the precision grip







Control of fingertip forces during object manipulation



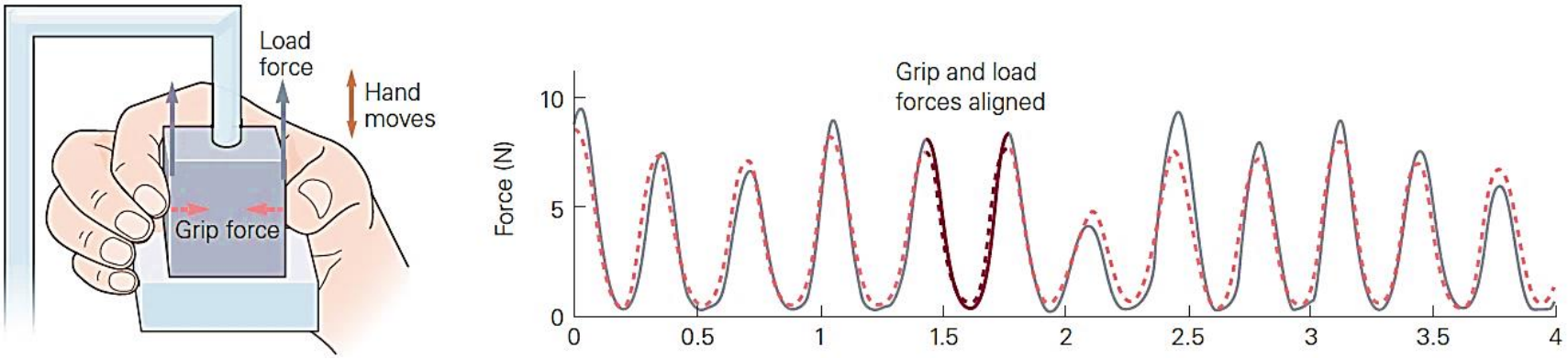
The control of ***grasp stability*** entails both the prevention of accidental slips and the prevention of excessive fingertip forces.

To maintain grasp stability, the *grip:load force* ratio must exceed a critical value, called the ***slip ratio***, which corresponds to the inverse coefficient of friction between the object and the hand.

To prevent slip and possible loss of the grasped objects the *grip:load* force ratios have to exceed the slip ratio. Accordingly, ***safety margin*** against slips is the difference between the grip:load force ratio applied by a subject and the corresponding slip ratio.

Anticipatory control policy
Load-grip force coupling

Human subject controls load force (planned movement)

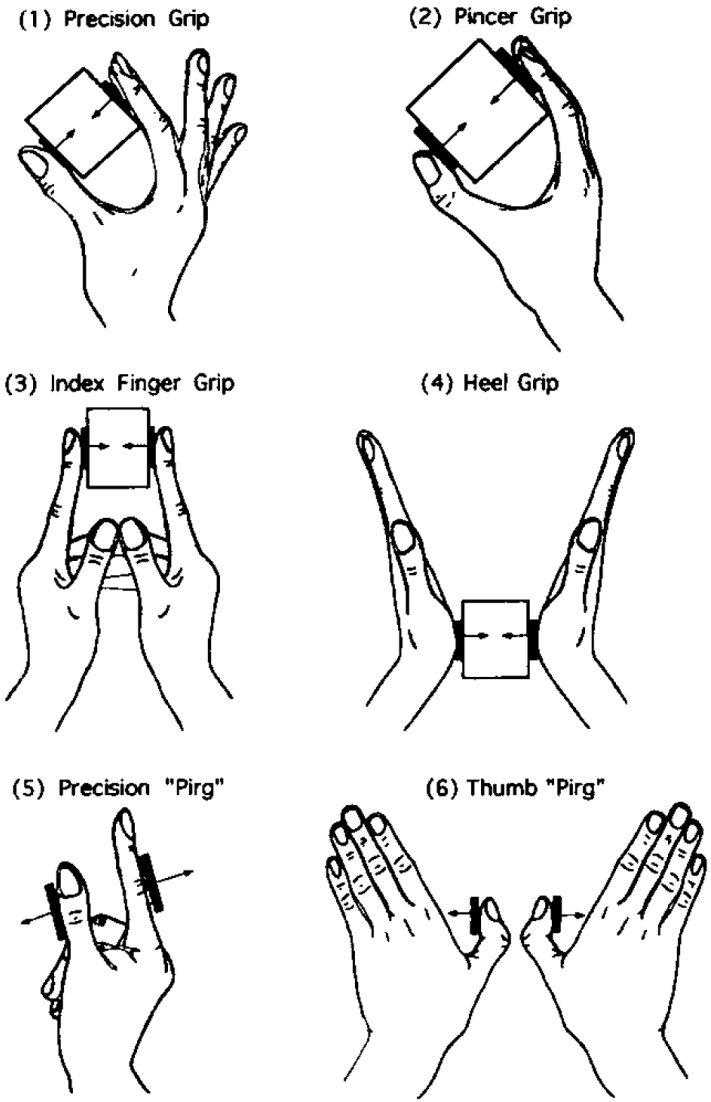


Kandel Fig 33.16

Human subject makes movement: predictive feedforward control

When the subject actively moves object up and down producing a load force, this load force can be anticipated and thus the grip force is exactly as high as needed at every point in time and tracks the load force without delay.

Load-grip force coupling: a general control strategy

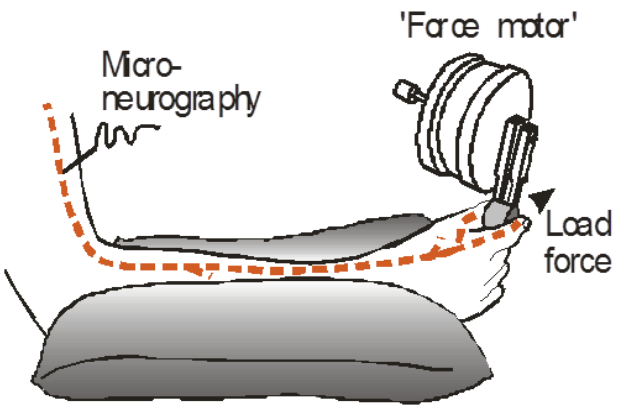


In all grips, grip force is modulated in phase with fluctuations in load force that are induced by the arm movement indicating anticipatory feedforward control strategy. Note that feedback control would inevitably cause a phase shift.

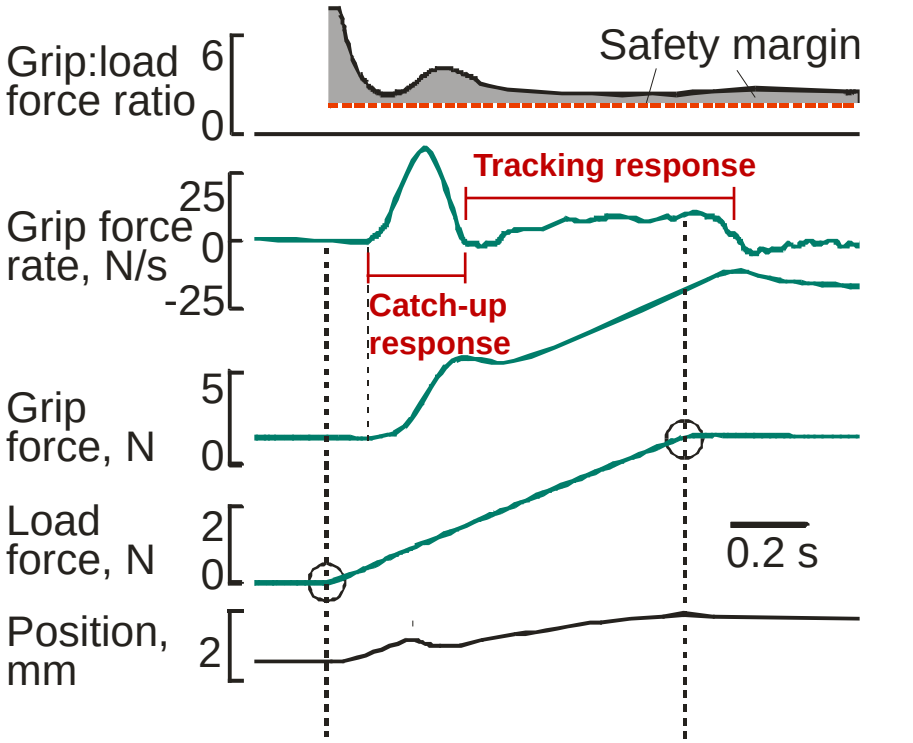
- The grip force is modulated in anticipation of changes in load force generated by active movements, regardless of the grip type and muscles involved.
- The tight temporal coupling between grip force and load force during object transport reflects a general control strategy that is not specific to any particular grip or mode of transport.
- Grip controller intelligently incorporates movements of the arm as well as whole body (e.g. jumping).

Flanagan & Tresilian., *J Exp Psychol Hum Percept Perform*, 1998

Responses to unexpected loading



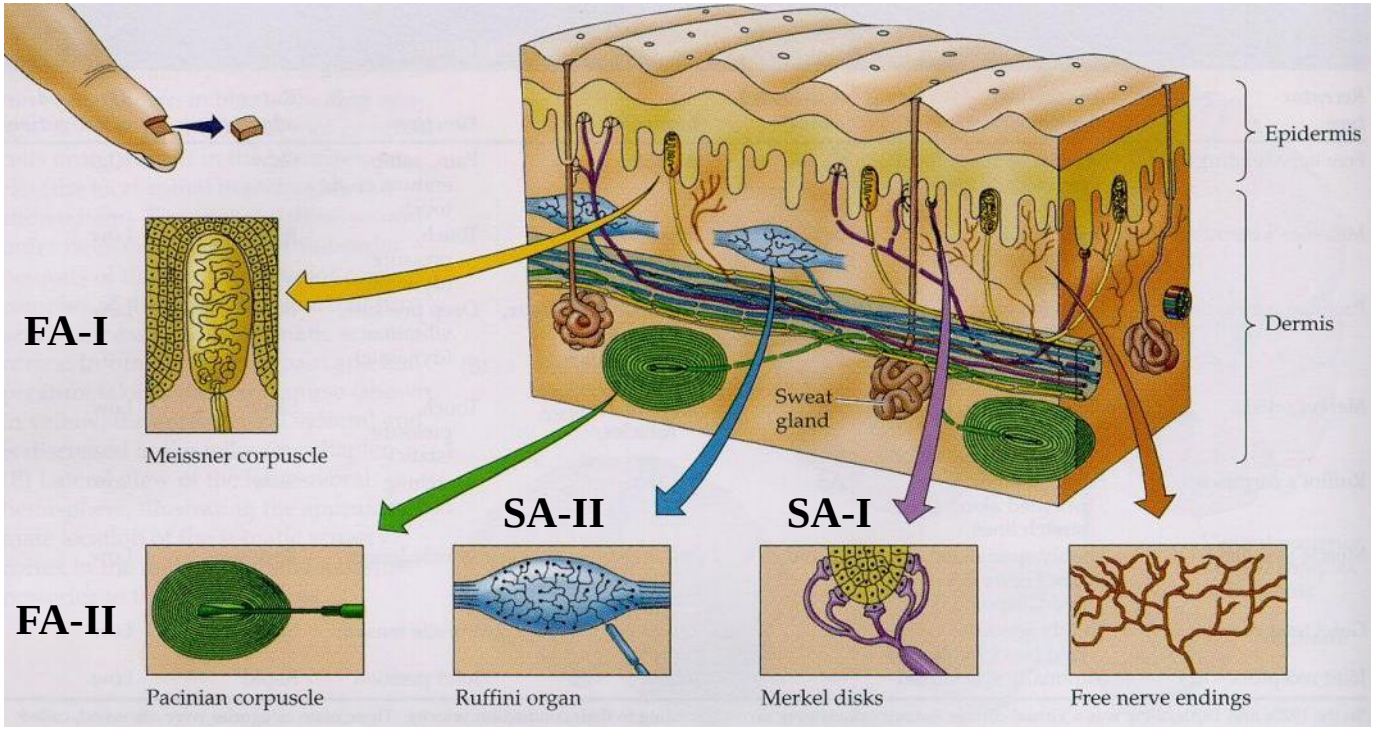
Johansson et al. Exp Brain Res, 1992a



This stereotypical automatic response typically consists of two main components: a brisk grip force increase called ***'catch-up response'***, followed by a grip force increase that runs in parallel with the increasing load force called the ***'tracking* response'.**

The catch-up response is scaled by sensory input (rate of the load force increase and friction) at the time of its initiation to compensate for delay due to reaction time.

The role of fingertip tactile receptors in control of hand's ability to handle objects



Vibroreceptors 30Hz and 250Hz

Stretch

Pressure

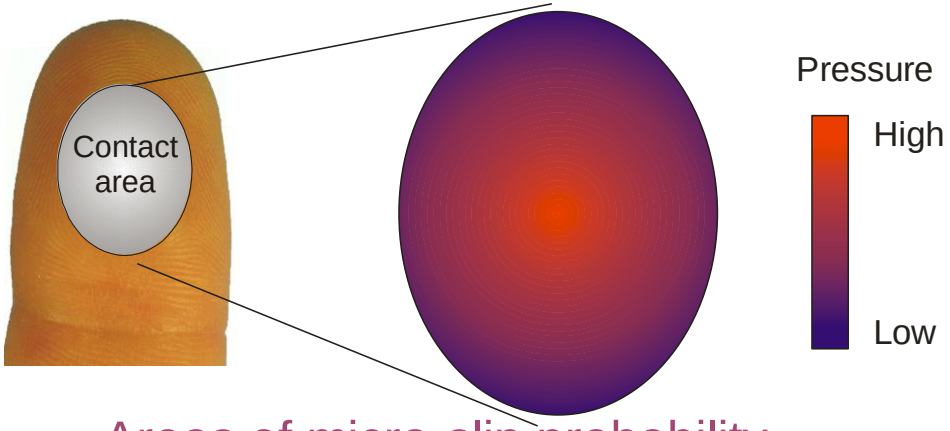
Pain, temperature

Fast Adapting (FA) type I&II receptors detect dynamic changes

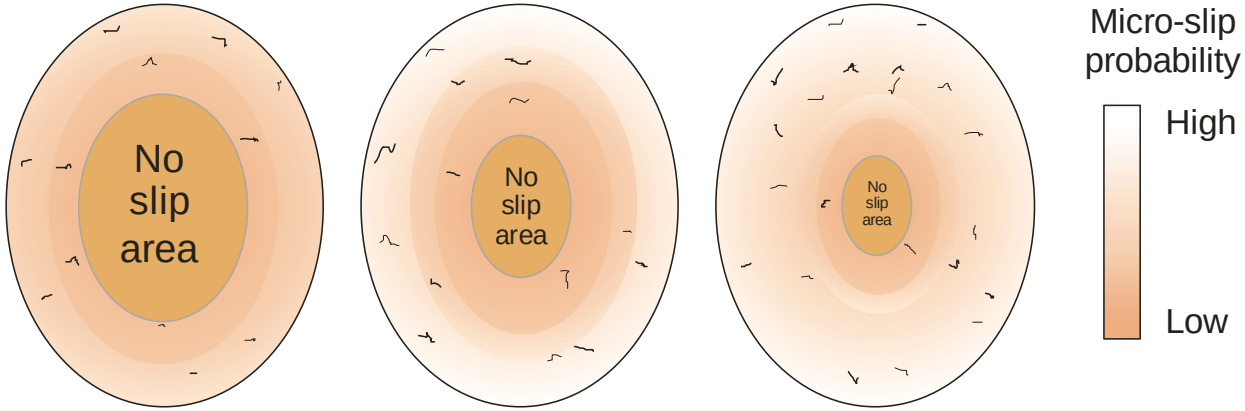
Slowly Adapting (SA) type I&II receptors; signal static stimulus features

Encoding of friction - hypothesis of underlying biomechanical mechanism

Pressure distribution within contact area



Areas of micro-slip probability

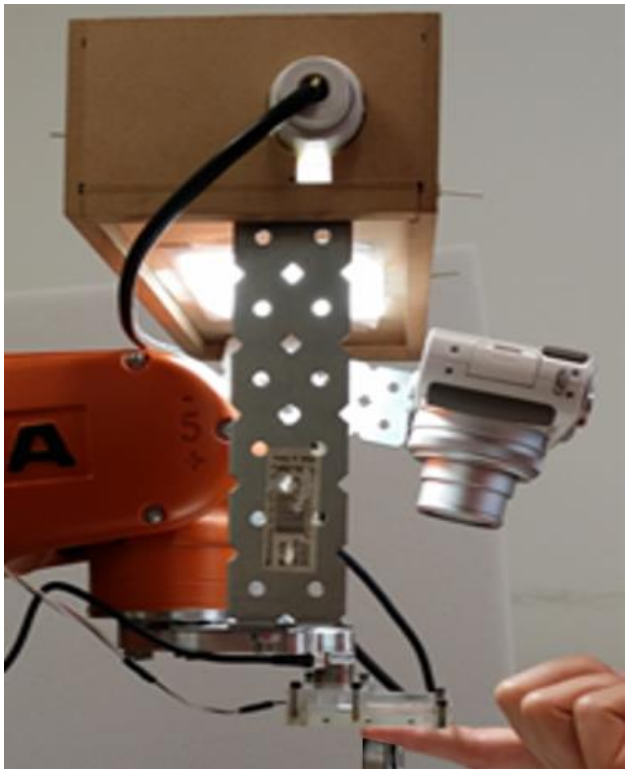


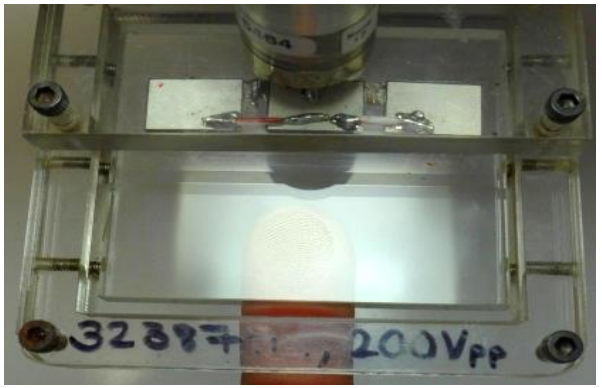
High friction

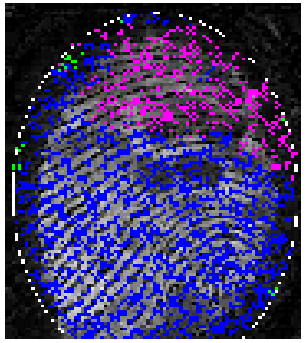
Intermediate

Low friction (slippery)

Experiments to investigate biomechanical mechanism of friction encoding





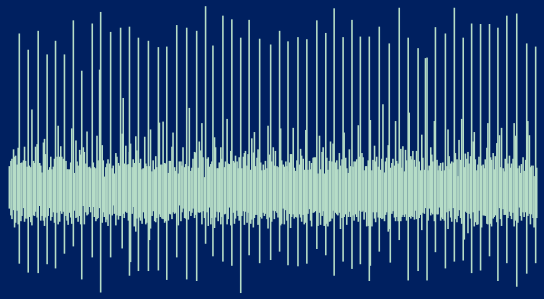


The setup consists of a robotic manipulator applying normal and tangential forces to the fingertip, ultrasonic friction modulation device (friction plate), light source to generate high contrast fingertip image as light is absorbed where fingertip skin ridges contact the friction plate. Fingerprint before the tangential force was applied and processed fingerprint image showing tracking points in blue and micro-slips in magenta when normal:tangential force ratio was approaching the slip ratio.

Fingertip tactile receptor responses

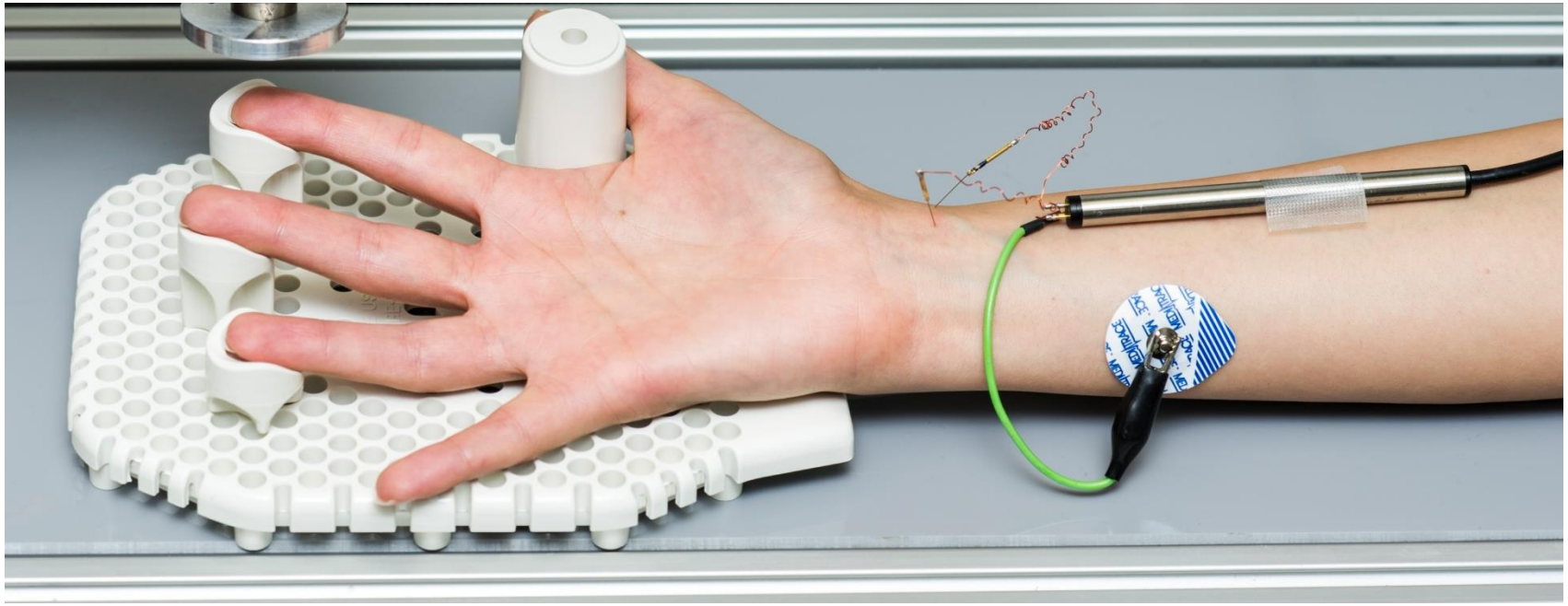
Human microneurography recording signals received from tactile receptors

Tungsten microneurography electrode inserted in a fascicle of human Median nerve

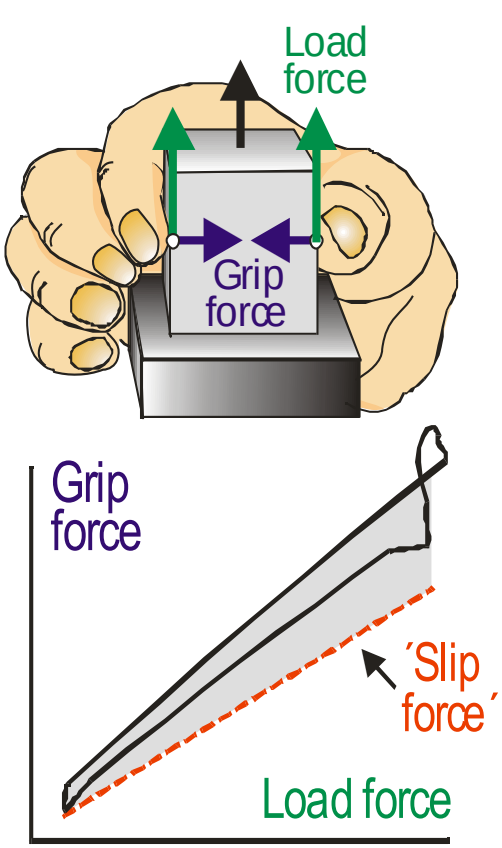


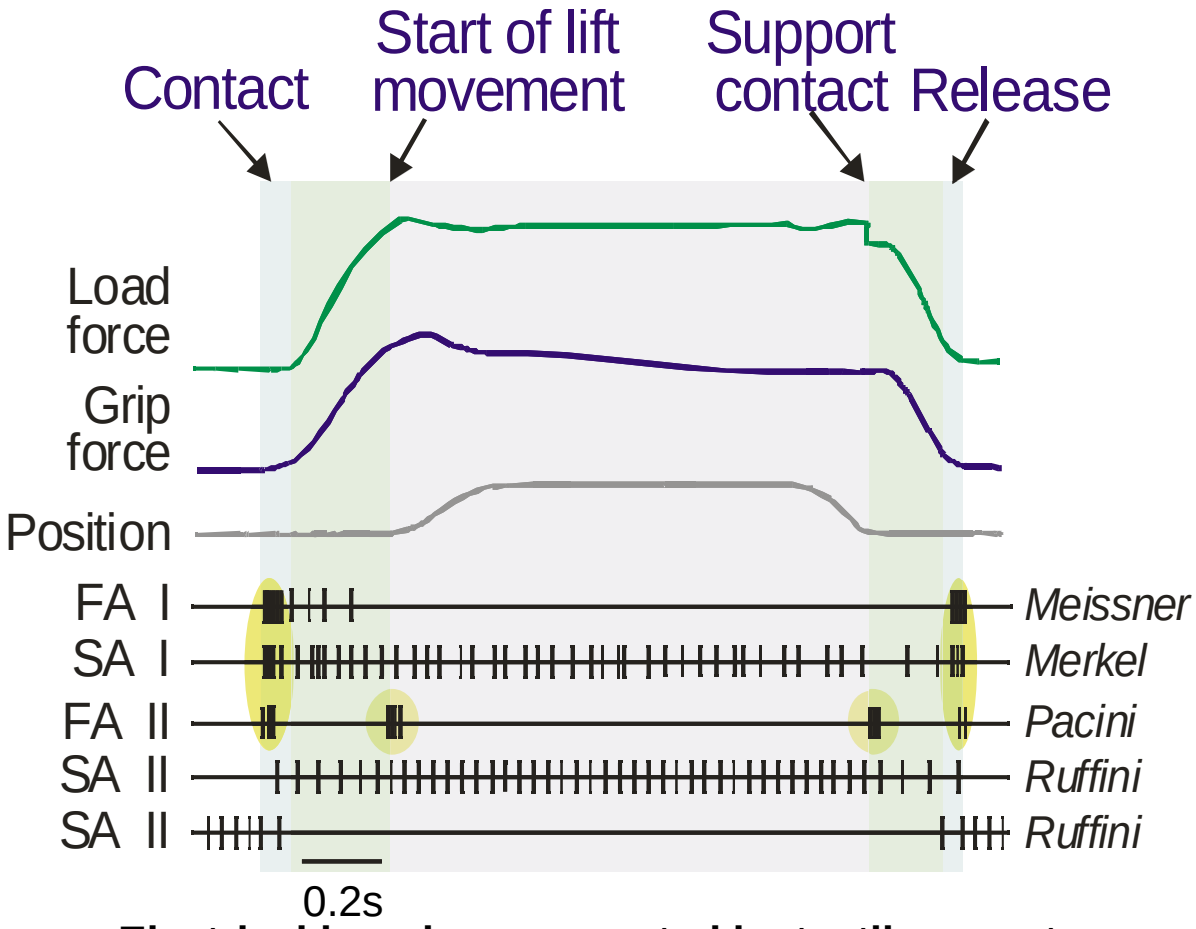
Nerve signal in form of electrical impulses - action potential or spikes (digital code)

Human microneurography recording signals received from tactile receptors



Role of signals received from tactile receptors





Electrical impulses generated by tactile receptors

Anaesthesia of the digital nerve

Will it ever be possible to match the dexterity of human hand?