Coding in the tactile system

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The outside of a perceptual system

The image flakes (idols, εἴδωλα) of Democritus & Epicurus

outside

inside the perceptual system
Two determinants reign on the outside of perception

1) The Physical Constraints – how are the sensory data conveyed to the sense organ?
2) Ego Motion – the behavioral strategy to collect sensory data
**Touch with fingers or whiskers are active scanning systems**

**Active scanning**: deploy energy into the world and make use of its reflections

- Echo location in whales/bats
- Electric sense of fish
- And touch

E is movement, but what is $E'$ ???

Roughness! Hardness! Slipperiness!
The physical constraints: Slips

What is shared by these objects?

They are cause or effect of frictional movement!

Frictional movement is characterized by stick-slip movements.
Slips are discrete, temporally local informational events…

…not unlike spikes in a neuronal network!
Determinants of (active) touch: friction and scanning strategy

1) The Physical Constraints – the sensory data are conveyed via frictional movement (slips)

2) Ego Motion – movement parameters (setpoint, speed, etc.)
**Slip hypothesis**

- Microscopic texture properties (e.g. roughness) are encoded in frictional slips.
- Encoding in short-lasting slip events (< 15 ms) begs a temporally local code rather than the classically discussed global codes.

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**Local, instantaneous code**
- Extraction of a kinematic feature of a local event (e.g. max position, velocity, acceleration, etc.).

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**Global, code**
- Intensity: $\sum$ average of some sort (e.g. sum of squared speed = power)
- Frequency: spectral analysis (e.g. best frequency, spectral centroid)
The slip hypothesis may provide an answer to the question why we have a fingerprint, and explain the exquisite structure of papillary ridges and related mechano-sensors.
Whiskers seem to be made for slipping

Towal et al., 2011
Voges et al., 2012
Hires et al., 2013
Slips are converted into strongly amplified moment events along the whisker
Biomechanics: Local coding is better than global coding

whisker A2

identification of one sandpaper out of five
chance level $p=0.2$

context:
- distance:
  - tip
  - 3/4
  - half
- speed:
  - 600 °/s
  - 1200 °/s
  - 1800 °/s

f (frequency), i (intensity)
sa (slip acceleration)
f/i/sa (all three)
Psychophysics and S1 spikes: Strongly indicative of coding of short (local!) events

Local and global (frequency)

Local and global (intensity)

global (intensity plus frequency) NO local code !!

S1 spikes

stim-change reward

S- S+ S- ...

+24 Hz

+7.2°

30 units

firing rate (Hz)

0 0.2 0 0.2

peristimulus time (s)

Δamplitude (deg)

Δintensity (deg/s)

rat 1

rat 2

0 1

0 4 8

0 400 800

p(r)
Psychophysical experiment in humans

“Indicate if you perceived a stimulus change!” (Yes / No)

Battarjee et al. Bioarxiv 2019
Performance is worst when maximal absolute velocity is kept constant
Summary

1. Frictional movements fundamentally transform 3D surface information into series of slip events embedded in noise.
2. Slips relay high rates of texture information.
3. Slips are susceptible to sensor movements.
4. Slips generated at the tip of the whisker are instantly conveyed to the base by 2nd mode of bending.
5. The moment is amplified by a factor of ~1000 from tip to base.
6. The information reaching the brain is about kinematic details of slip-like events - short strips of trajectory, 10 ms in duration.
7. Rats extract tactile information contained in slip-like short events rather than integrating the signal.
8. Humans extract information contained in short events
9. **Slip hypothesis**: Tactile perception depends on event waveforms – less on integrated variables.