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On the relationship between neural coding and the perception of the present moment.

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Abstract

Our perception of the present moment differs from the physicist's perspective, where the both the moment and the minimum detectable time interval are infinitesimally short. As William James noted in1890, "the sensible present has duration", and that duration, is not fixed, but is variable length, up to a few seconds, much longer than a physicist's moment. But what gives it its duration? Even single celled organisms (at least from a behavioral perspective) do not appear to "experience" time as physicists describe it, but have a number of timescales. For these, there is always context, implemented by the internal content of the cell, in turn modulating the pores (channels) of the cell, and the sensors and actuators on the cell surface, so that the cell's behavior depends not just on the instantaneous environment, but on the environment over some period. For animals with neural systems, (perceptual) context is implemented primarily neurally. Neural coding takes time: a single spike is the shortest possible code, but both rate coding and codes formed from combinations of spikes (except absolutely co-incident spikes) all take time to form. Cognitively speaking, we live "in the present moment" (from a 1st person perspective), but what does this mean? Is it an issue of single neural coding, or are there signaling cycles involved? The duration of the "sensible present" suggests something different from simple rate coding, or single spikes: yet the speed of the effect of (particularly unexpected) sensory stimuli suggests that the "present moment's" percept can be altered by a relatively small number of spikes. This suggests some connection to dynamic patterns of activity. The duration of the "sensible present" is affected by what the person is doing. It does appear to have a minimum length, but, for example, in meditative states, where attention is not given to stimuli, it can be short, yet where attention is involved (like playing a piece of music on an instrument, or scoring a goal in football), it can be extended. This suggests that a number of collaborating neural effects cause the build-up of the "sensible present". There is clearly a subjective element in the concept, making it difficult to measure. We propose a cortical basis for the shortest element of the perceptual present.

The nature of the present moment.

Perceptual time is different from physical time.
Not surprising: perceptual images are different from the light that causes them, and perceptual sound differs from the pattern of pressure waves that are the physical bases of perceptual sound.

What is known about perceptual time?
Dunne 1925 (An experiment with time) [1]
"attention is never really confined to a mathematical instant. It covers a slightly larger period"
But what is ***the duration of the present instant?***
Also known as *the specious present* and the *mental present* (Stroud)
Two different interpretations
1. The period below which the present seems indivisible: set to 40 to 50ms by von Baer and Poppel
2. The period for pre-sematic temporal integration, set at about 3 seconds by Poppel.

How long does a coherent percept take to form?
Visually? Auditory? Olfactory? Tactile? Or cross-modal?

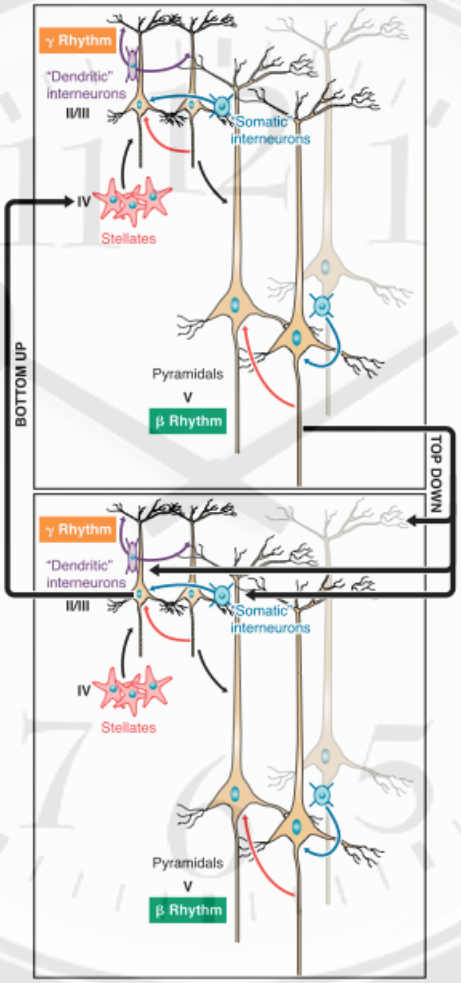
What evidence is there for a perceptual minimum time of 40-50ms?
Auditory domain:
Increases in energy in different areas of the auditory spectrum
...onsets (including vowel onsets /s/ onsets, etc.).
Appear to need to be within 40-50ms if they are to be considered as a single entity

A click train at 18-20 clicks/second fuses into a single percept.

Visual domain:
A sequence of images above about 18-20 images/second fuses into a movie.
Still some flicker, at 18-20 images/second, but unified percept is perceptually convincing.

But how is perceptual time constructed?

This is as good a question as those related to sensory percepts, for example seeking the neural construction of olfactory, sound, or visual percepts.



Two interconnected columnar elements from cortex: each oscillates in gamma frequency band, and interconnection is excitatory => inhibitory, enabling rapid in-phase synchronized oscillation across the cortex. Figure from [2].

From physical to perceptual time

What is the nature of time (at a behavioral level) for a single cell?
What sets the time constants?
What is changing?
Ions (and other materials) crossing the cell membrane
DNA-driven protein manufacture
DNA replication (for mitosis) (etc.)

What is the nature of time for single cells with mechanical appendages (flagella, for example)
Flagella have mechanical properties that govern how rapidly they can move, or oscillate
Different time constants: depending also on cell type.

What is the nature of time for simple multi-cellular animals (without a neural system)
Diffusion across cells:
Cross-membrane transfers
Gap junction transfers
Cell-to-cell communication

What is the nature of time for multi-cellular animals with neural systems?
What is the nature of "perceptual" time for these?
What sets the time-constants?
What is the neural construction of perceptual time?

On the neural construction of perceptual time

Temporal context in a neural system
The effect of a spike always has both a spatial and a temporal context
That is, a spike's effect is determined by
Which axon the spike arrives from
Which other nearby axons (innervating the same neurite) have spiked recently.
e.g. in an LIF (point) neuron, the context is summarized by the activity level; in a more realistic neuron, the local activity level, plus other factors all can have an effect; in a real neuron, local ionic concentrations, plus neuromodulators etc.
For human (and higher animals) perceptual time is probably a cortical construct.

(There are always philosophical and methodological issues connecting perceptual (1st person) reality and neural activity. That perceptual reality has a neural construction appears to be generally agreed, yet avoiding the homunculus issue seems difficult, unless the neural activity directly gives rise to the first person experience of being. We therefore assume that neural activity does directly gives rise to the first person experience of being, although we do not understand the mechanisms by which this happens.)

Whittington et al [3] suggest that there are specific temporal patterns *within* the gamma-period of cortical columns, characterizing (coding?) the input to that column. These appear good candidates for atomic individual percepts, since (i) columns are locations at which sensory activity is integrated and (ii) they are of approximately the correct duration. Placing the percept at the columnar level also helps explain why auditory, visual, and audiovisual percept minimum length are approximately the same.

Further, longer-range synchrony mediated by cortical principal neurons exciting inhibitory interneurons (see Figure) could permit construction of more complex, longer term percepts from the single column "atomic" percept elements by synchronization.

What experimental evidence is there for this, beyond the coincidence of the time duration? What form might such experimental evidence take? How one might interpret this to provide synhetic systems with perceptual time is discussed in [4].

References

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4. **Smith L.S. (2012),** Perceptual time, perceptual reality, and general intelligence, to appear in Proceedings of Artificial General Intelligence, Oxford, 2012