Unified framework for the perception of stimulus intensity and stimulus duration in humans and rats

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The nervous system can extract multiple perceptual features from a single sensory stream. Presented with a tactile vibration, for instance, we perceive both its intensity and its duration. How are different dimensions of a single stimulus read out from the brain to generate separate perceptual properties? Are the dimensions independent or else interacting?

Here we present behavioral experiments, in both human and rats, to determine whether, and how, stimulus intensity and duration interact in the perception of both features. In the first experiment, subjects receive two vibrations (Stim1 and Stim2) delivered either to their fingertip (humans), or whiskers (rats). Vibrations are normally distributed velocity noise, defined by mean speed and by stimulus duration. Subjects can be rewarded either for detecting the relative mean speeds of Stim1 and Stim2 or the relative durations of Stim1 and Stim2. In the speed discrimination task, unequal duration of Stim1 and Stim2 leads to a perceptual bias corresponding to an overestimation of the intensity of the longer stimulus both in humans and rats. In the duration comparison task humans and rats over-estimate the duration of the higher-intensity stimulus. Thus, longer feels stronger and stronger feels longer.

In Experiment 2, in order to quantify the interaction of perceived duration and intensity, we designed a task in which human subjects have to estimate either the duration or the intensity of single vibrations by scaling their judgment through a slider. This experiment reveals that both the percepts – duration and intensity – are generated using “universal” variables simultaneously. We thus propose a unified model that supports the idea that a common network can dynamically extract duration or intensity from the same vibration in a task-dependent manner.

Our model is able to replicate, (i) the bias by which subjects judge longer stimuli as being more intense, (ii) the bias by which subjects judge stronger stimuli as being of greater duration.

Neural recordings in behaving rats from our Lab, revealed that neurons in the barrel (primary somatosensory) cortex do not show the temporal integratory properties that could explain the duration-intensity perceptual confound. In contrast, premotor cortex neurons do express the computations inherent to the model and confirm that both intensity and duration of the stimuli are encoded by the same neural population.