Computational and Representational contributions to intensity invariance in Weber's Law

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Behavioral invariances are typically assumed to depend on invariant neural representations, i.e., to have a representational origin. A case in point concerns the mechanisms underlying Weber's law (WL;[1]), which states that the discriminability between two stimuli depends on the ratio of their intensities, and is thus invariant to overall multiplicative changes in amplitude.

We recently showed that WL in sound lateralization coexists with reaction times (RTs) that are lawful but not invariant to overall level[2]. Both RT and accuracy are very accurately described by a model based on bounded accumulation of evidence where the decision variable (DV) does not possess invariance to overall intensity. Instead, WL holds due to the dependence of the commitment probability on the mean and variance of the evidence[3].

We have now analyzed a massive dataset of 30 rats performing this task in over 1.6 million trials using a wider range of sound lateralization levels. The data displays tight adherence to WL and its associated RT regularity, but our previous model is not accurate for the largest lateralization levels. We show that accounting for these differences requires a partial level of explicit divisive normalization (DN)[4] in the sensory neurons conveying the evidence.

A single model parameter interpolates between varying levels of DN. At one extreme (purely representational invariance) the DV is completely level invariant and so are accuracy and RT (unlike the experiments). At the other extreme lies our previous model (purely computational invariance), which fails for large level differences. A model with an intermediate level of DN accurately describes accuracy and RT across all conditions, suggesting that both evidence accumulation and divisive normalization are necessary. We conclude that both computational and representational mechanisms contribute to Weber's Law.

Weber's law, perceptual decision making, drift diffusion model, reaction time, divisive normalization.