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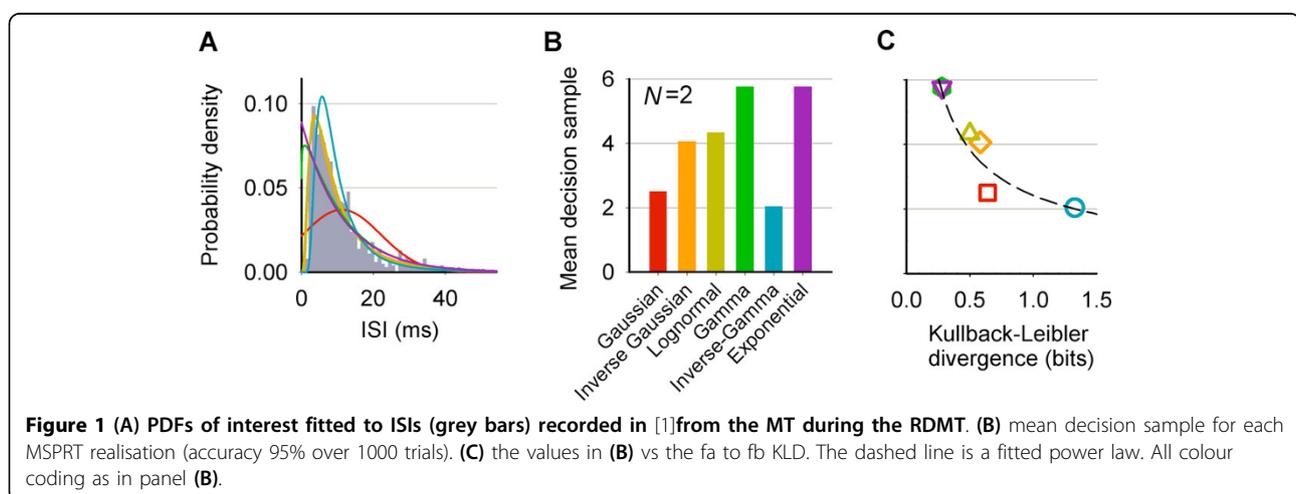
# Decision-making out of neural events: from discrimination information to psychometric power laws

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The strength/intensity of the stimulus in the random dot motion task (RDMT) [1] is determined by the percentage of dots in the kinematogram moving towards a saccadic target,  $a$ . Due to the uncertainty in the stimuli, neurons in sensory systems have evolved to transform environmental information, comprising evidence upon which a decision can be made (e.g. saccading to  $a$ ). The neurons in the middle-temporal area (MT) appear to produce such evidence during the RDMT, given their tuning to a 'preferred' direction of visual motion. If the dots move predominantly in the preferred direction of an MT neuron, it generates inter-spike intervals (ISI) supporting a saccade to  $a$ . These ISIs seem randomly sampled from a distribution,  $f_a$ , with mean,  $\mu_a$ . Otherwise, the ISIs follow another distribution,  $f_b$ , with mean,  $\mu_b$ , where  $\mu_b$  is larger than  $\mu_a$  and this difference increases

with stimulus strength. The accuracy vs motion-strength function of an ideal observer provided with empirical distributions like  $f_a$  and  $f_b$ , from a single MT neuron, approximates the subject's psychometric function (at the behavioral level) [1]. The distributions  $f_a$  and  $f_b$  are non-negative, positively skewed and have a mode larger than 0 (figure 1A), as is typical for neural events recorded in many brain areas. Here we investigate why this is advantageous for decision-making. As theoretical decision-making units, we produced 5 new instantiations of the multi-hypothesis sequential probability ratio test (MSPRT) [2]. Each unit assumes its stream of input evidence to follow 1 of 5 probability density functions (PDF) whose compatibility with the empirical distribution of ISIs varies (figure 1A). These include the Inverse Gaussian, Lognormal, Gamma, Inverse-Gamma and Exponential



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PDFs (the latter is the distribution of the inter-event times in the oft-used Poisson process). Under equal and appropriate conditions, we then compared their mean decision sample with that of an MSPRT instantiation that assumes Gaussian inputs proposed in [3] and discussed in general in [4], as exemplified in figure 1B. The mean decision sample is the mean number of observations required by a unit to identify which of  $N$  parallel information sources supports saccading to  $a$ , with a given accuracy. This decision sample is a model of the 'neural decision time'; the psychophysical reaction time also includes sensory and motor delays. The pattern of our results is explicable using a measure of the discrimination information between  $f_a$  and  $f_b$ , i.e. the Kullback-Leibler divergence (KLD). We found that, the mean decision sample decreases with increasing  $f_a$  to  $f_b$  KLD and, crucially, this follows a power law (figure 1C). At the behavioral level, Piéron [5] reported the mean reaction time to the presentation of a stimulus (go/no-go decision-making) being shorter for more intense stimuli, and that a power law relates these measures. The universality of Piéron's law indicates that it can inform us of something fundamental about sensorimotor decision-making. Our results suggest that its explanation could lie in the power law relationship between the mean neural decision time and the discrimination information (KLD) among the distributions of sensory evidence.

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