Role of the cost of plasticity in determining the features of fast vision in humans.

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Several studies have demonstrated the usefulness of general principles of computational efficiency and maximum information preservation in predicting even rather detailed properties of early vision [1,2,3,4].
While all these studies have deeply examined the efficiency of the computation involved in the processing that actually occurs during the early visual analysis, not much attention has been devoted to the issue of the complexity of the computation required to determine the base ingredients of that processing themselves (neural Receptive Fields). Indeed, some of those algorithms require rather complex calculations in order to determine the shape of the RFs.
Considering the plasticity of the visual systems, one might expect that the algorithms employed by the visual system should not only be economical to execute, but also reasonably economical to set up, and to update when adapting to varying external conditions.
In this regards, it is an interesting question whether there are examples where the visual system has made a choice that is suboptimal from the point of view of the run-time performance, but lends to easier and more efficient updates and improvement. In this work we present results of a psychophysical experiment that appears to be such an example.
We start from a model of early vision[5], where the general principle of computational optimality takes the form of a maximization of transferred entropy within a limited bandwidth and from a fixed, finite number of discrete patterns, that are assumed to be the only information recognized by the system. This approach captures very well the problem faced by a system with finite computational resources, and has proved to be very effective in practice, in describing the actual human performance in fast vision in a number of situations[5,6]. In addition, it lends very well to comparing the properties of mathematically optimal solutions to approximate, and therefore sub-optimal, solutions that easier to compute and update.
Specifically, the optimality condition that is imposed to the set of RF in this approach, can be formulated as a case of a class of well-known problems that go under the name of "knapsack problems" [7]. These problems admit exact numerical solutions, that in the general case are rather expensive to compute, and simpler approximate solutions that are slightly less optimal, as the one that has been heuristically adopted in Del Viva et al.[5]. We have found that application of these approaches to the extraction of optimal visual patterns lead to similar but nonetheless clearly distinguishable solutions, raising the interesting question of which of the two better describes the actual performance of fast vision in human subjects.
By performing psychophysical experiments we found clear evidence that the actual performance of human vision is in agreement with the simpler approximate solution rather than the mathematical optimum. While the latter is slightly better from the point of view of computational efficiency of the image analysis, the simpler solution is much easier to determine and update in case of the need to adapt to changes of the external conditions.
This experimental result thus seems to be evidence for a well-defined role of the "cost of plasticity", in shaping the features of the visual system.

References

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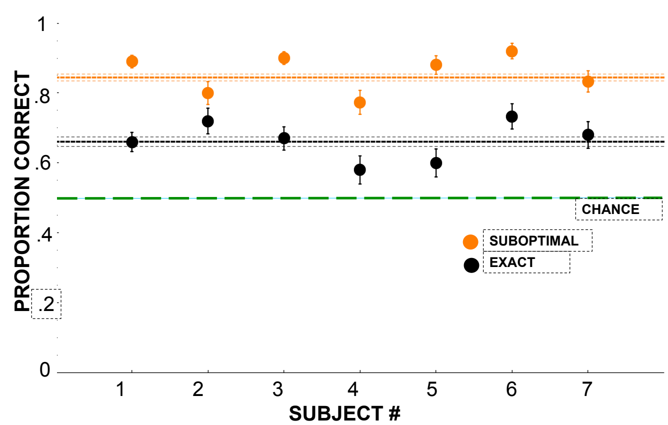

Figure 1 Psychophysical discrimination of stimuli (2AFC procedure) composed of patterns (features) obtained with the exact (black) and sub-optimal (heuristic) 2-dimensional solution to the *knapsack problem*