A response to the "Decadal Survey of Social and Behavioral Sciences and Applications to National Security"

To survive in a hostile and changing world, successful organisms must solve a handful of basic problems: they must find food, shelter, and mates while avoiding predators and other threats. Given the complexity of the environment, each of these necessities is, effectively, a massive and ongoing data-processing challenge, and one that must be met accurately and efficiently. Emerging insights from many domains (including olfaction[4,5], somatosensation[1,7], vision[1,2,6], and the electric sense[3]) converge on the notion that the biological solution is not merely to learn a set of filters and features, but rather, to learn an integrated sensorimotor strategy for actively exploring the environment[1-4, 6,7] and adapting to it.

Although each organism's niche, along with its individual repertoire of sensors and effectors, might allow for highly individualized solutions, the logic of evolution, as well as empirical evidence, suggests that successful organisms' solutions share fundamental design principles and algorithms. Identifying the commonalities is likely to provide a path to develop advanced engineered systems -- especially when such systems include sensor technologies that are without direct parallel in animals, such as LIDAR and multispectral imaging.

Fruitful research directions foreseeably include understanding how biological systems find "sweet spots" along a wide variety of dimensions, ranging from organismal behavior to neural mechanism to algorithm. These include (i) balancing robust strategies that work in a broad set of conditions with ones that are more efficient, but more fragile; (ii) grappling with the "explore vs. exploit" gamut, and, more specifically, crafting strategies for sampling the environment in space and time; (iii) balancing the utility of computations that are mathematically near-optimal but costly to implement with that of computations that may be less than ideal but more suited to biological hardware (and whether our current normative notions are in fact correct), and (iv) the utility vs. burden of constructing different kinds of cognitive maps and representations[8] for different purposes.

Research that can achieve these insights is likely to be highly multidisciplinary: the desired understanding requires advanced and comprehensive measurements of environmental statistics, large-scale recording of neural activity and behavior (including but not limited to traditional "model species", and in paradigms that sharply test candidate models -- for example, by perturbing neural activity, altering the environment, or opening the sensorimotor loop), and modeling both at the theoretical and computational level.

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Jonathan D. Victor

jdvicto@med.cornell.edu

Professor, Neurology and Neuroscience

Feil Family Brain and Mind Institute

Weill Cornell Medical College