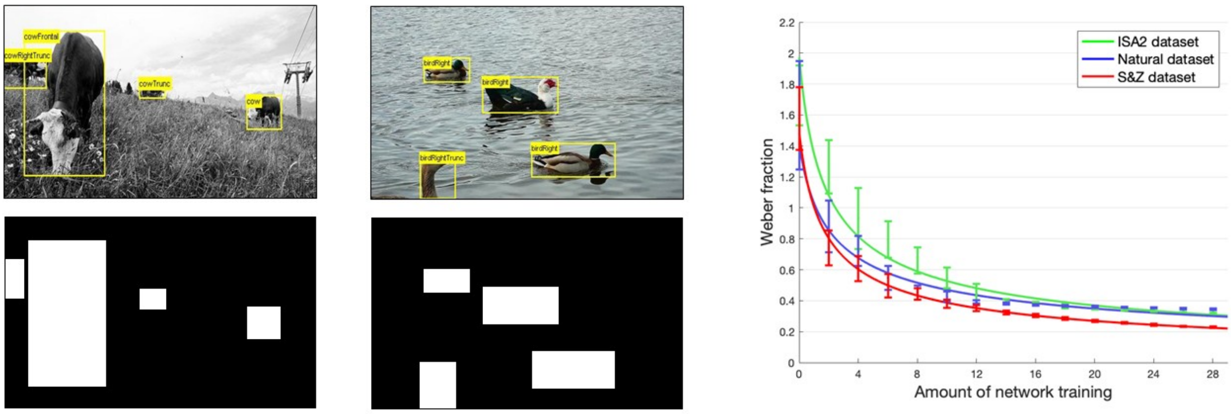
Simulating the development of “number sense” in children



Several studies have shown that children – and even newborns – have remarkable cognitive abilities. In the domain of numerical cognition, for example, it seems that infants can perceive numerosity information from the first days of life, by creating an approximate representation of the number of objects present in a visual scene. Such ability, often referred to as “number sense”, gets progressively sharper during development.

In Lab experiments, the number sense is usually measured by means of numerosity discrimination tasks, where two stimuli containing a different number of objects are shown, and the participant should indicate which stimulus has the largest numerosity. The change in response accuracy with respect to the numerosity ratio allows to compute a psychometric index, called “Weber fraction”, which represents the numerical acuity of the participant and which gradually improves (that is, decreases) during development.

In this study, carried out in collaboration with colleagues at Stanford University, we simulated the mechanism underlying number sense development using a computational model based on artificial neural networks. The neural network initially exhibits a quasi-random structure, since the strength of synaptic connections is initialized with random values; however, following a repeated exposure to a set of visual stimuli (digital images containing a variable number of objects) the connections are adapted through an unsupervised *learning algorithm*. This mechanism allows to simulate the plasticity of synaptic connections in the human brain and to compare the developmental trajectories of artificial neural networks with those observed in children.

The model accurately reproduces the progressive development of number acuity in humans, exhibiting different developmental trajectories depending on the statistical properties of visual stimuli used during the “training” phase. For example, learning is slightly faster when all numerosities (from 1 to 32) have the same frequency and numerical information varies orthogonally with total area (luminosity) of the stimuli, compared to a more ecological condition where stimuli were taken from natural scenes, which often contain few objects and where numerical information is usually correlated with total area.

Besides clarifying what could be the mechanisms underlying the development of our number sense, this research work opens the possibility to more accurately simulate how machines can acquire cognitive skills, thus creating a further bridge between human and artificial intelligence.

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