# More variability found to help learning

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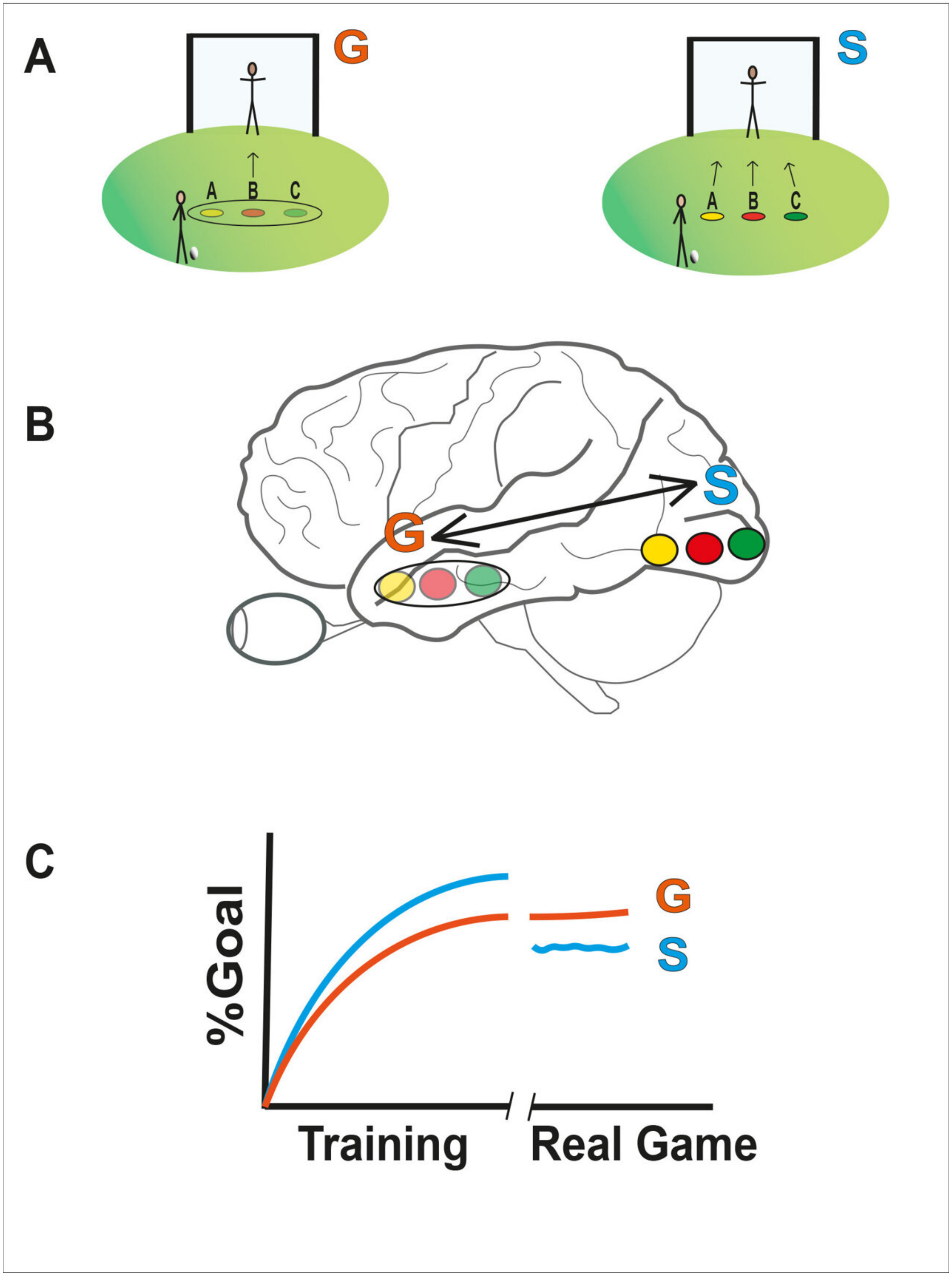
A
G
A
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G
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Training
Real Game

A: A soccer player who always trains to hit the goal from the same positions A, B and C can improve and learn the general movement to reach the goal (generalization = G) or he can learn the very detailed shot angles and distances from A or B or C to the goal (specialization = S).B: In the specialization strategy, the task is processed at the neural level by three different groups of brain cells that are highly sensitive to each specific position. Thus, for example, the neurons encode the angle from A to the goal, the distance from A to the goal, and likewise for positions B and C. These neurons are normally located in the early steps of sensory processing (marked with blue S). In the generalization strategy, other neurons are used due to the heterogeneous training. These react less to aspects like angle or distance. Thus, learning is controlled by neurons that are responsible for the goal-scoring itself and not for the details of the different positions. These neurons are generally located at higher levels of sensory processing (marked with red G).C: During real play, the player who learned with neural strategy S will decrease in accuracy because he is unable to generalize learning to new positions outside of A, B, or C. The player with learning strategy G, on the other hand, achieves high performance in scoring the goal. Credit: Giorgio Manenti, DPZ

The World Cup final is in full swing, the stadium is filled to capacity, the fans are roaring, there is a flurry of flashbulbs. A free kick taker gets ready, takes a run-up and shoots. He had practiced free kicks a thousand times beforehand, but only on his home training ground and not in a crowded and noisy soccer stadium with changing lighting conditions and changing shooting positions. Will he still manage to score?

Neuroscientists at the German Primate Center (DPZ)—Leibniz Institute for Primate Research and at the European Neuroscience Institute (ENI) in Göttingen wanted to find out how our visual system solves the challenge of variable stimuli for learning processes.

Are there strategies at the neuronal level that lead to the task nevertheless always being performed with the same performance? In a study with human subjects, they found that many variable stimuli do not necessarily make learning a task more difficult, but can even lead to better performance under new conditions.

This happens through a generalization process controlled by neurons in higher areas of the visual system. In this process, they only process task-relevant information such as the shot into the goal. They are less sensitive to irrelevant stimuli such as other lighting conditions or shot positions. As a result, a task can still be performed safely even if irrelevant stimuli are constantly changing. For the soccer player, this means that variable training situations are beneficial for the learning process.

A fundamental problem of perception is to filter out relevant information from a highly variable environment. It is known that the visual system achieves this by learning which information is constant. For example, we always recognize a dog as a dog, even if our point of view changes or it wears a dog jacket. This generalization process improves perceptual performance and is called perceptual learning. How the enormous variability in the environment affects this learning process was unclear until now.

"In our study, we wanted to find out how the visual system copes with the challenge of variability and still achieves high learning performance," said Giorgio Manenti, lead author of the study. "Previously, it was assumed that variable stimuli primarily affect the visual learning. However, this variability can also be a great advantage for learning, as it can facilitate generalization, the application of learned behavior to new stimuli. This has not yet been shown for visual perceptual learning."

The researchers based their study on two hypotheses. In the generalization strategy, learning relies on neurons that ignore unimportant stimuli. Thus, in the example of the free kick taker, they process only the information about the goal shot, but not the different shot angles or distances to the goal. These neurons generally sit in higher steps of sensory processing.

In the specialization strategy, learning operates via neurons that are closely tuned to both task-relevant and irrelevant features. These neurons can provide highly accurate information for the task at hand. In doing so, they process each piece of information separately. As a result, task performance is very accurate, but no generalization occurs, and each new task requires new, previously untrained neurons to process the stimuli. Specialized neurons are located in early steps of sensory processing.

In this study, four groups of subjects were trained to detect small differences in the orientation of a line pattern. The relevant task was to detect the clockwise or counterclockwise slope of the lines. For each of two groups, the number of lines was changed during the experiment. This was the irrelevant stimulus.

"We found that varying the number of lines during training led to better generalization of the actual task performance," explains Giorgio Manenti.

"The subjects were still able to recognize the differences in the orientation of the line pattern, even when the number of lines was changed. They were able to perform the task even when they were shown entirely new line patterns or a new position on the screen that had not appeared during training. Thus, the increase in variability did not cause the learning process to deteriorate, but rather to generalize and even improve learning performance."

Computer simulations of the training programs in artificial deep neural networks confirmed the generalization strategy conjecture. "Overall, the study shows that the type of training can influence the brain's learning strategy and thus possibly also the place where learning takes place in the brain," said Caspar Schwiedrzik, head of the Perception and Plasticity research group at DPZ and Neural Circuits and Cognition group at ENI, summarizing the work.

"You can also say that training in vision is similar to training principles in soccer. In both, more variability in training leads to being better able to meet new challenges."

The research was published on the *bioRxiv* preprint server.

**More information:** Giorgio L. Manenti et al, Variability in training unlocks generalization in visual perceptual learning through invariant representations, *bioRxiv* (2022). DOI: 10.1101/2022.08.26.505408

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