

V3A takes over a job of MT+ after training on a visual task

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A person's performance on a perceptual task can be significantly improved by repetitive training on the task. This improvement is termed perceptual learning and is regarded as a manifestation of adult plasticity in perceptual and brain processing (1). To date, detailed neural mechanisms of perceptual learning have yet to be completely understood. The recent study by Chen et al. in PNAS (2) advances the understanding by showing that transfer of perceptual learning of 100% coherent motion to noisy motion is associated with dramatic changes in involved neural sites.

Distinguished from other types of learning and memory, many types of perceptual learning occur only for the trained feature and its presented location (3, 4). Such specificity has been interpreted as a manifestation of involvements of local circuits in early sensory cortical areas, which generally have smaller receptive fields than higher level cortical areas in perceptual and brain information processing (5).

However, it has also been suggested that, as perceptual learning proceeds, those neural sites involved sometimes shift from higher-level cortical areas to lower-level ones (6). More recently, it has been found that, if some methods are combined with traditional training methods of perceptual learning, perceptual learning of a stimulus at a location in the visual field is transferred to other locations (7, 8). These findings have

attracted a great deal of attention because they suggest that neural sites involved in perceptual learning include brain regions beyond early sensory areas. These results are also consistent with the model that reweighting between sensory processing and perceptual decision underlies perceptual learning (9–11).

Chen et al. have developed an ingenious experimental design to examine how two different areas, V3A and MT+, are involved in perceptual learning of a coherent motion task and its transfer to a different type of motion. Before training, participants' performance was measured for two types motion stimuli, 100% coherent motion and 40% coherent motion, presented on different sides of the visual field. A 100% coherent motion display consisted of dots, all of which move at the same direction and speed. A display with 40% coherent motion consists of only 40% of dots moving coherently while the remaining 60% of dots move randomly and therefore is regarded as a noisy motion display.

Next, to examine brain areas that play significant roles in processing 100% and 40% coherent motions, transcranial magnetic stimulation (TMS) was applied on a region of the scalp close to V3A in one group of participants and to MT+ in the other group. The V3A-disturbed group showed impaired performance on discrimination of 100% coherent motion directions, whereas the MT+-disturbed group showed impaired performance on discrimination of 40% coherent motion directions. These results suggest that V3A plays an important role in processing 100% coherent motion, whereas it is MT+ that plays a significant role in processing a noisy 40% coherent motion.

Then, both groups were trained on direction discrimination only with 100% coherent motion for 5 d. As a result, participants showed task performance improvement not only with 100% coherent motion but also with 40% coherent motion. Because 40% coherent motion was not trained, perceptual learning of 100% coherent motion transferred to 40% coherent motion.

After this training, TMS was again applied to V3A to the same V3A-disturbed group of participants and it was applied to MT+ to the same MT+-disturbed

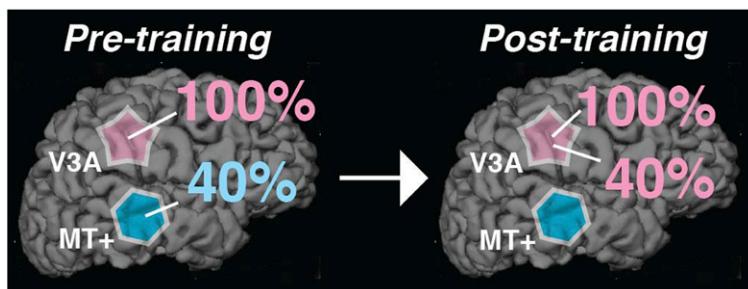


Fig. 1. Before training, V3A plays a significant role in processing 100% coherent motion, and MT+ in 40% coherent motion. However, after training, both V3A plays important roles in processing both 100% and 40% coherent motion and MT+ no longer plays a significant role in processing 40% coherent motion.

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group of participants. The V3A-disturbed group showed impaired discrimination performance on both 100% and 40% motion, whereas the MT+-disturbed group showed no change in performance with or without TMS. These results demonstrate that, after training on 100% coherent motion, V3A took away the perceptual learning job for 40% coherent motion from MT+ (Fig. 1). The results further suggest that training dramatically changed the weights of involvements of V3A and MT+ in motion direction discrimination. This is in accord with the reweighting model of perceptual learning that assumes perceptual learning is associated with changes in weights in cortical connections (10).

However, this is not the end of the story. Chen et al. present evidence that a representation of motion direction within V3A also changed due to training. With a new group of subjects, Chen et al. used functional magnetic resonance imaging to test whether a representation of motion direction changed in V3A and MT+, in a very similar experimental design to the previous except that no TMS was applied. A decoding analysis was conducted to classify functional magnetic resonance imaging activation patterns evoked by the trained direction and the direction orthogonal to the trained for 100% and 40% coherent motion. Before training, decoding accuracy for the 100% coherent motion was higher in V3A than MT+, whereas decoding accuracy for 40% motion was higher in MT+ than V3A before training. After training, decoding accuracy for both 100% and 40% became higher in V3A than MT+. In other words, the quality of the neural representation in V3A also changed.

Taken together, Chen et al. demonstrate that perceptual learning of 100% coherent motion transferred to noisy 40% coherent motion with shifts in the neural site involved in noisy coherent motion from MT+ to V3A possibly by changing the balance in the information relay between regions involved in sensory processing and perceptual decision, as well as changing a sensory representation of noisy motion in V3A. Chen et al. suggest that training on 100% coherent motion improved a representation of the trained motion direction within V3A as well as an increased resilience to noise in 40% coherent motion.

Shifts in neural sites have been reported in different contexts for learning and memory. Acquisition and consolidation of motor skill learning shift in neural sites involved (12). Declarative memory also seems to shift neural sites for its storage over time (13, 14). In perceptual learning with monkeys, it has been found that after

coarse disparity discrimination training reversible inactivation of MT devastated coarse discrimination performance, whereas after fine disparity discrimination training inactivation of MT did not impair coarse discrimination performance. This result also suggests that training can change brain sites involved in task performance (15). Generally, for the sake of efficiency in memory and learning processing, involved brain sites may be dramatically changed as well as local circuits within these sites (16).

The study by Chen et al. raises interesting questions. First, what neural mechanisms are involved in learning transfer to an untrained visual location? In the present study, perceptual learning was observed only in the location in which the trained stimulus was presented. However, in some cases, perceptual learning is transferred to untrained visual field locations (7, 8). Second, would similar results be observed in perceptual learning of other sensory features and its transfer? If so, what areas are involved? V3A and MT+ are largely involved in motion processing. However, perceptual learning and transfer of learning occur when visual features other than motion trained (7, 15). Third, after the training in the present experiment, MT+ no longer showed a critical role in processing of 40% noisy motion. Does this indicate that MT+ simply stops processing motion signals or changes its role for something new? Fourth, is task involvement during training necessary for the observed shift in neural sites? It has been shown that perceptual learning of a feature results from not only training on a task on the feature but also exposure to the feature that is irrelevant to the task (17–19). It would be highly interesting to test whether the transfer observed in this study and associated neural shifts occur as a result of mere exposure to 100% coherent motion task-irrelevant.

Many researchers used to believe that, after a visual critical period, no major changes occur in sensory and perceptual abilities. Perceptual learning with adults counters evidence of that belief. Although initial studies of perceptual learning showed changes in local circuits involved in the trained feature, recent studies including the one by Chen et al. (2) have indicated that perceptual learning is also associated with a larger-scale changes.

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