



T<sub>1</sub> (N = 21, S = G520, 1024 × 768; 0.37 × 0.37; 120 Hz; 50. / s<sup>2</sup>), D = P1130 (1024 × 768; 0.37 × 0.37; 150 Hz; 41. / s<sup>2</sup>).

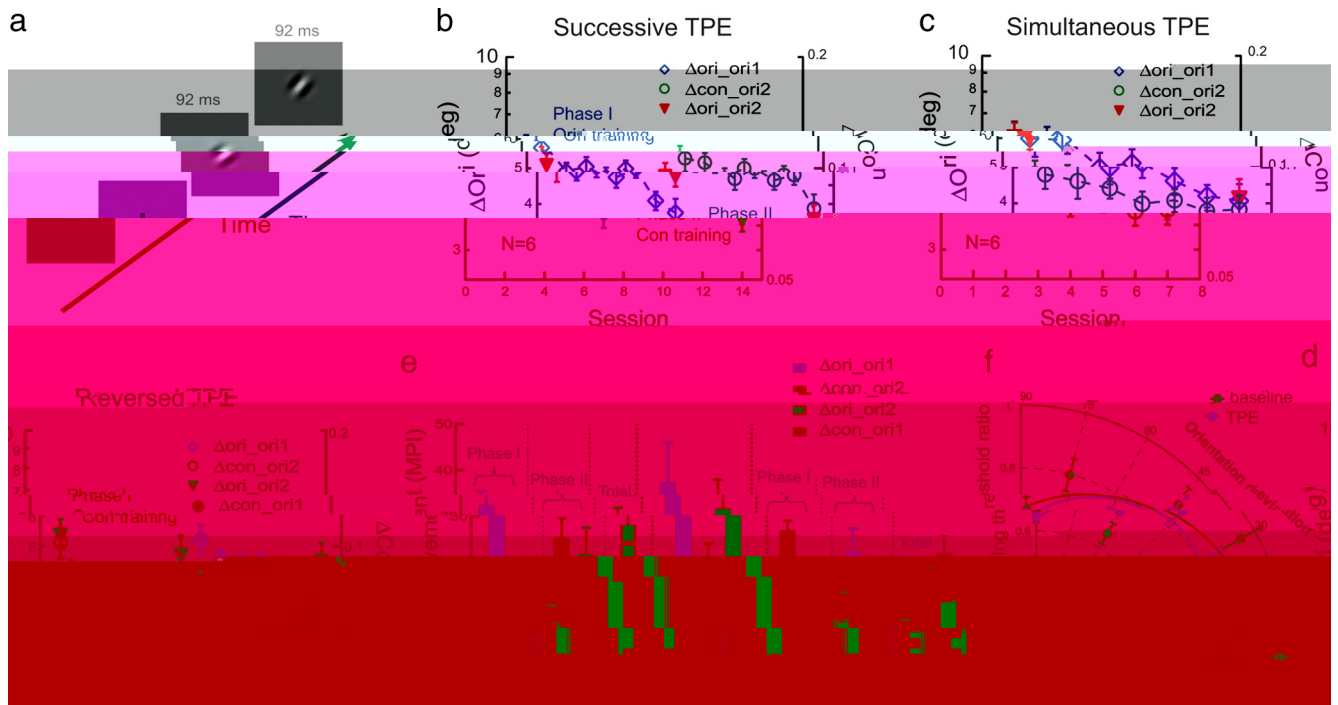
Stimuli. T<sub>1</sub> (G = 6, SD = 0.17, = 0.47, (Eq. 1a), (Eq. 1, 2). T<sub>1</sub> = 17).

(Eq. 3a), A. H. (1997). S<sub>1</sub> (7 × 7, 22.2 × 1.3), 42.5 ± 3.9, 2. T<sub>1</sub> (Eq. 3a), 16. T<sub>1</sub> (SOA), 7 × 7, 90.

Procedure. C (2AFC) (Δ + Δ) (92, 600). T<sub>1</sub> (200). T<sub>1</sub> (200). T<sub>1</sub> (SOA). T<sub>1</sub> (50%). A. T<sub>1</sub> (79.4%). T<sub>1</sub> (0.05). E. T<sub>1</sub>.

**Results**  
**Orientation specificity and transfer in orientation learning**

W. S. (W, ?) G. (Eq. 1a) (36, 126, Δ = 1, 1). A. 2,



**Figure 1.** Perceptual learning of orientation discrimination and its transfer to a second orientation studied with TPE procedures. **a**, The stimulus configuration for orientation discrimination in which one interval contained a more clockwise Gabor stimulus. **b**, Successive TPE procedure. Phase I (sessions 1–7): orientation discrimination was practiced at one orientation (36°/126°,  $\Delta_{ori\_ori1}$ , blue diamonds); orientation thresholds indicated by the left ordinate and the transfer of learning was tested at an untrained orthogonal orientation (126°/36°,  $\Delta_{ori\_ori2}$ , the left two red triangles), which replicated typical orientation specificity in orientation discrimination learning. Phase II (sessions 8–14): the same observers were later exposed to the transfer orientation ori2 in a contrast-discrimination learning task around the same transfer orientation (126°/36°,  $\Delta_{con\_ori2}$ , green circles; contrast thresholds indicated by the right ordinate) and the transfer of orientation learning to ori2 was remeasured (126°/36°,  $\Delta_{ori\_ori2}$ , the right two red triangles). Thresholds are averaged over all observers' data; error bars represent one SEM. The left and right ordinates have the same scale factor in log units. **c**, Simultaneous TPE procedure: orientation discrimination was practiced at ori1 ( $\Delta_{ori\_ori1}$ , blue diamonds) while the transfer orientation ori2 was exposed in a contrast-discrimination learning task ( $\Delta_{con\_ori2}$ , green circles) and the transfer of learning was tested for orientation discrimination at ori2 ( $\Delta_{ori\_ori2}$ ; red triangles). **d**, Reversed TPE procedure. Phase I (sessions 1–7): contrast discrimination was practiced around ori2 ( $\Delta_{con\_ori2}$ ; open green circles) and the change of orientation discrimination performance was measured at ori2 ( $\Delta_{ori\_ori2}$ ; left two red triangles). Phase II (sessions 8–14): orientation discrimination was practiced at ori1 ( $\Delta_{ori\_ori1}$ ; blue diamonds) and the transfer of learning was measured at ori2 ( $\Delta_{ori\_ori2}$ ; right two red triangles). The untrained contrast threshold at ori1 ( $\Delta_{con\_ori1}$ ) was also measured after the TPE procedure (solid green circle with black outline). **e**, A summary of learning and transfer. Left, Successive TPE in **b**; middle, simultaneous TPE in **c**; right, reversed TPE in **d**. **f**, The average posttraining/pretraining threshold ratios at various orientation deviations from the transfer orientations (36°/126°) with conventional (red circles, fitted with a Gaussian peaked at 0° orientation deviation) and TPE training (blue circles, fitted with the difference of two identical Gaussians peaked at 0° and 90° orientation deviations).

... 2 ( $\Delta_{ori\_ori2}$ ;  $MPI = 26.9 \pm 2.1\%$ ,  $p < 0.001$ ) (E, 1d,e), ... ( $\Delta_{ori\_ori2}$ ;  $MPI = 7.7 \pm 5.8\%$ ,  $p = 0.083$ ).  
 I ... TPE, ... ( $\Delta_{ori\_ori1}$ ;  $MPI = 22.2 \pm 5.1\%$ ,  $p = 0.004$ ) (E, 1d,e). H ... ( $\Delta_{ori\_ori2}$ ;  $MPI = 5.0 \pm 2.6\%$ ,  $p = 0.053$ ) (E, 1d,e). T ... TPE ...  
 D ... TPE, ... ( $\Delta_{ori\_ori1}$ ;  $MPI = 22.6 \pm 3.6\%$ ,  $p = 0.001$ ) (E, 1d, ... ) ... ( $\Delta_{ori\_ori2}$ ;  $p = 0.13$ ), ... H ... TPE ... TPE ...

TPE ... H ... TPE ...  
 ... 2 ... 1 ... 2 ...  
 ... 1, T ... 2 ...  
 W ... TPE ... E ... TPE ...  
 ... 0, 15, 30, 45, 60 ... (36, 126) ...  
 T ... 2. A ...  
 W ... TPE ... (E, 1f). B ... 30 ... TPE ...





(M. D., 1996; L. G., 2009). A TPE (E. 1d), I (J., 2009). A T. (E. 3), (A., H., 1997, 2004). R. H. TPE, (E. 3) (D. L., 2007). E. TPE (E. 1b, 3c). S. (S., W., 2005).

**A rule-based learning model**

Q. T.

*Rule-based learning*

E. VI. H. F. G. T. VI.

*Rule application: specificity and transfer*

Q. T. W. VI. (T., 2001; V. S., 2005; G., 2009), VI. O. (E. 1, 3) (X., 2008).

VI. A. TPE (E. 1d). I. R. W. F. W. I. ~200 (Z., 2010), W. (S., 1995).

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