

Vernier perceptual learning transfers to completely untrained retinal locations after double training: A “piggybacking” effect

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Perceptual learning, a process in which training improves visual discrimination, is often specific to the trained retinal location, and this location specificity is frequently regarded as an indication of neural plasticity in the retinotopic visual cortex. However, our previous studies have shown that “double training” enables location-specific perceptual learning, such as Vernier learning, to completely transfer to a new location where an irrelevant task is practiced. Here we show that Vernier learning can be actuated by less location-specific orientation or motion-direction learning to transfer to completely untrained retinal locations. This “piggybacking” effect occurs even if both tasks are trained at the same retinal location. However, piggybacking does not occur when the Vernier task is paired with a more location-specific contrast-discrimination task. This previously unknown complexity challenges the current understanding of perceptual learning and its specificity/transfer. Orientation and motion-direction learning, but not contrast and Vernier learning, appears to activate a global process that allows learning transfer to untrained locations. Moreover, when paired with orientation or motion-direction learning, Vernier learning may be “piggybacked” by the activated global process to transfer to other untrained retinal

locations. How this task-specific global activation process is achieved is as yet unknown.

Introduction

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& D , , 1996; D & L , 1999; , K, , & L , 2004; P , , 2005).

H , 1997; J , D , P , & L , 2009).

I , , H , 1997).

H K, , L , & , 2012; , C , & , 2013), (PE)

K, , L , & , 2014; J. . & , 2014).

(J. . , 2010; J. . , C , & , 2014).

(J. . , 2010).

(, 2008). M (2013)

J , L , & L , 2013). L (D , - -)

H

Methods

Observers and apparatus

D (, 20). A,, I

(N 21- I M , - , O , , CA) G520 , , 1536 , , 0.19 (H) × 0.19 () , : 2048 , × , 75 H , : 1024 , × 768 , , 0.38 (H) × 0.38 () 50 / 2. 8- E

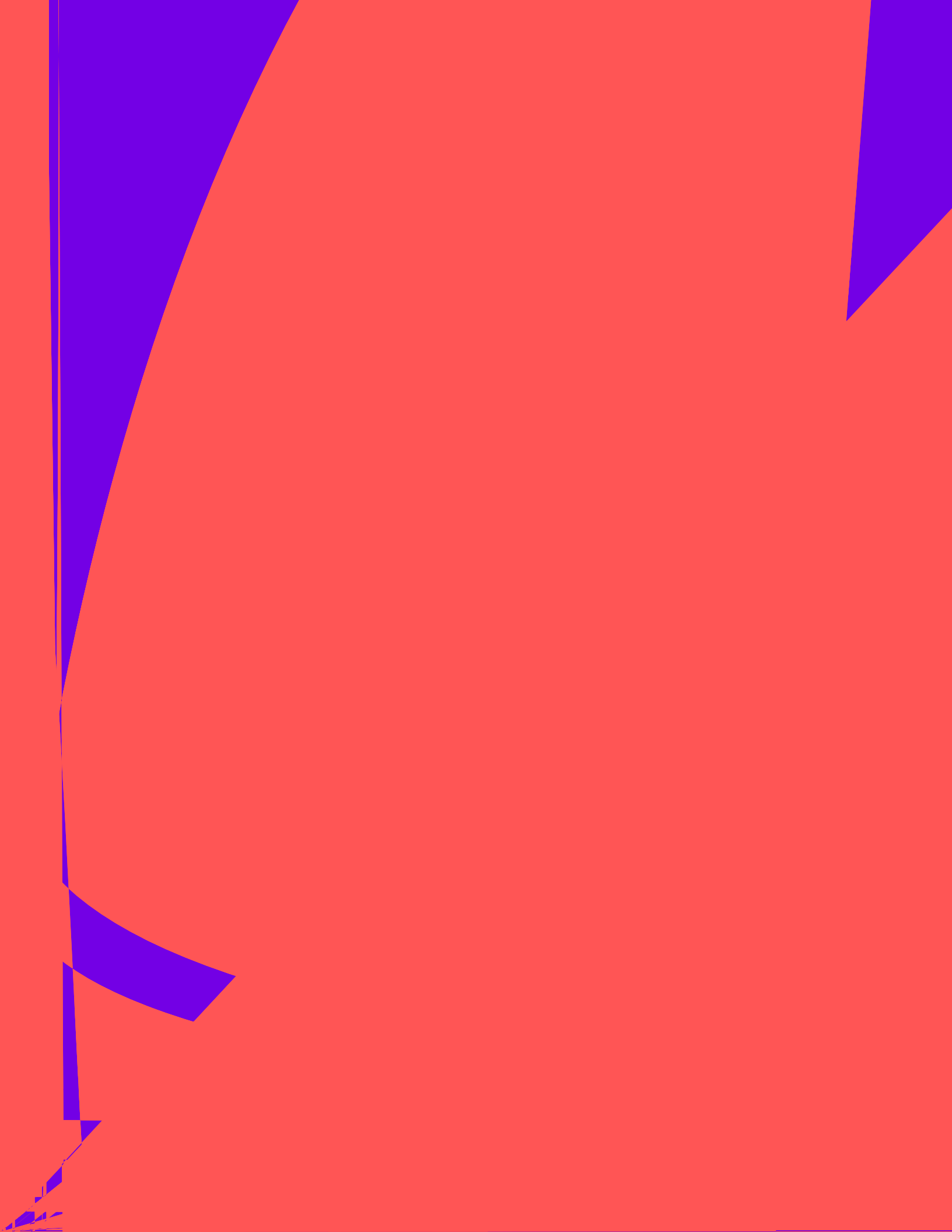
Stimuli

G (G - ,) (F , 1).

a

c

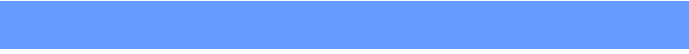
G (0.29°), (0.47), (3), (4 × 4), 25 ,
 (4λ. G , , ,) 2°- (F 1). E ,
 , , G , , 250 . , , ,
 , , , , , " (36° 126°) , . A,,
 ±15 0.47 7% . O , ,
 0.47 + ΔC. " 1.5 , ,
 0.75 , 5° 10° , . G (, = 1.5 ,



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Statistical analyses

$PI = 100\% \times (\quad - \quad) / \quad \cdot H$ (PI).
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I = 1 I = 0. p , , , p1 I



($F = 1$).

($F = 3$; $p = 0.008$; $I = 0$ ($p_0 = 0.26$; $p_1 = 1$), $p = 0.001$, $F = 1$), $(MPI = 37.2 \pm 2.9\%, p < 0.001$, $F = 1$), $(MPI = 31.6 \pm 6.4\%, p < 0.001$; $F = 1$), $(MPI = 41.0 \pm 8.4\%, p = 0.014$; $F = 1$), $(MPI = 35.9 \pm 4.1\%, p = 0.006$; $F = 1$),

$27.8 \pm 6.2\%$ ($p < 0.001$), $29.5 \pm 6.5\%$ ($p = 0.004$), $21.7 \pm 4.6\%$ ($p = 0.004$), $I = 0.69 \pm 0.15$ ($p_1 = 0.022$), 0.61 ± 0.11 ($p_1 = 0.011$), 0.87 ± 0.18 ($p_1 = 0.25$),

5° ($MPI = 20.1 \pm 7.0\%$, $p = 0.016$), $35.9 \pm 7.4\%$, $p = 0.002$, $MPI = 0.45 \pm 0.18$ ($p_1 = 0.003$), 0.92 ± 0.20 ($p_1 = 0.69$), 10° , $(MPI = 31.6 \pm 8.8\%$, $p = 0.008$), $28.4 \pm 6.6\%$, $p = 0.006$, $H = 1$, $H = 1$, 5° ($MPI = -0.5 \pm 10.7\%$, $p = 0.96$; $I = -0.12 \pm 0.41$, $p_0 = 0.39$), 10° ($MPI = 5.5 \pm 5.2\%$, $p = 0.34$), $(t = 2.39, df = 22, p =$

I, I 0.23 ± 0.12 ($p_0 = 0.13$)
 (t = 4.236, df = 14, p = 0.001).

(t = 3.63, df = 20, p = 0.002).

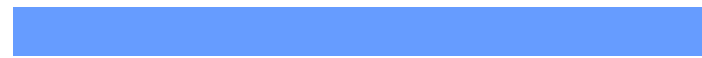
Double training with learning and actuator at the same retinal location

I F 1 (, 2008; , 2012; , 2013),
 H, F 1
 F 1
same
 same 5°
 (MPI = 37.3 ± 3.5%, p < 0.001; F 2)
 (MPI = 29.7 ± 5.4%, p = 0.002; F 2),
 (MPI = 29.9 ± 3.0%, p < 0.001,
 , 18 F 2)
 (MPI = 25.0 ± 3.8%,
 p < 0.001, 31.3 ± 5.1%, p < 0.001,
 I 1.00 ± 0.20 ($p_1 = 0.50$)
 0.99 ± 0.19 ($p_1 = 0.48$),
 (MPI = 29.5 ± 5.2%, p = 0.014),
 (MPI = -6.8 ± 12.9%,
 p = 0.83; I = -0.22 ± 0.41, $p_0 = 0.20$; F 1). H

Sequential double training and the effect of reversed order

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 2005).
 (F 3).
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 (MPI = 34.0 ± 5.8%,
 p = 0.002),
 (MPI = -4.1 ± 5.1%, p = 0.46; I =
 -0.1 ± 0.16, $p_0 = 0.26$),
 (MPI = 25.7 ± 3.7%, p < 0.001).

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 , 2AFC (F 2 -
 ; n = 5). B
 , 2AFC
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 B , , , 2011) . , ,
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