

P L I A A
T R -B C C

1, C, 1, A, 2, D, 2, C, 1

1D, DG/ G, B, k, C, k

2, B, G, C, B, k, C

C, D, 5, B, 100871, C, @, k

C, D, 5, B, 100871, C, @, k

D, 10, 2013

A, F, 10, 2014

C, C, A, D, C

Invest Ophthalmol Vis Sci.
2014;55:2020-2030. D
10.1167/13-13739

PROPOSE.

METHODS. (22.5) (E)

(E), F

RESULTS. F, F

F, F, 1.5, 1.6 ($P < 0.001$)

53% ($P < 0.001$).

CONCLUSIONS. k

A, 19, 21, 22

(E)

6, 7, 1, k, 23

2, 8, 24, 26

9, 11, k

3, 12, 13, F, 2, 4, D

14, 16, 17, 18, 2

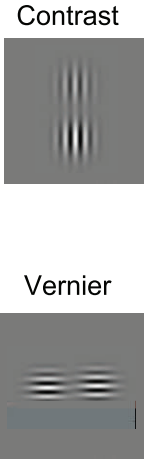
Investigative Ophthalmology & Visual Science



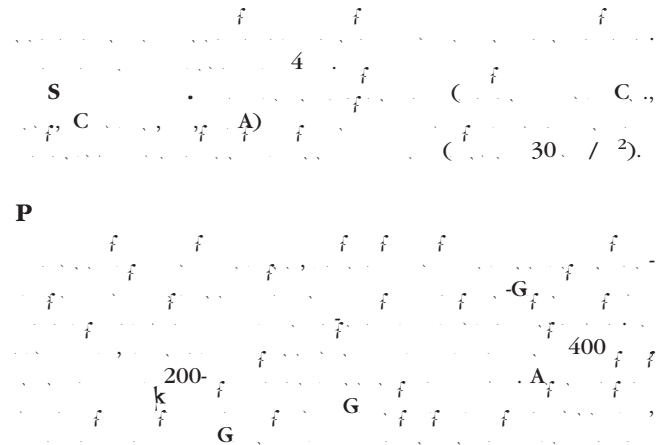
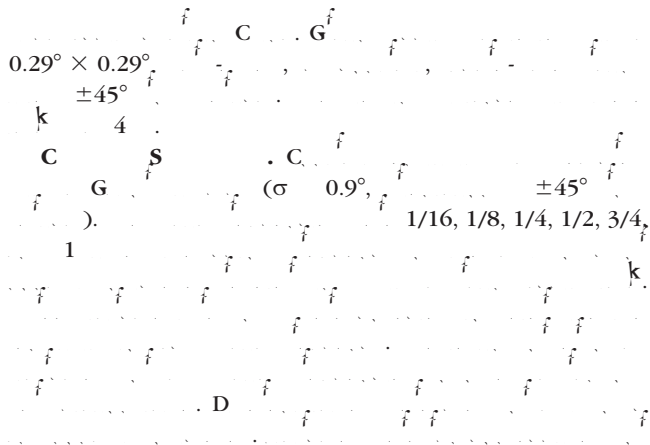
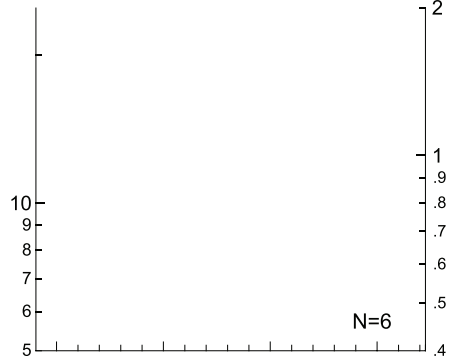
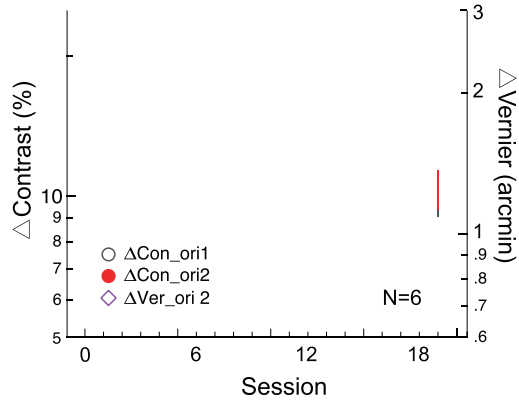
S
k (F = 1).
D = 0.7
2.4
2.7
8.2, D = 1.8
0.9
G (G
k
k (F = 2). G
(80%), (180°)
G
G
G
±50. (±2
G
G

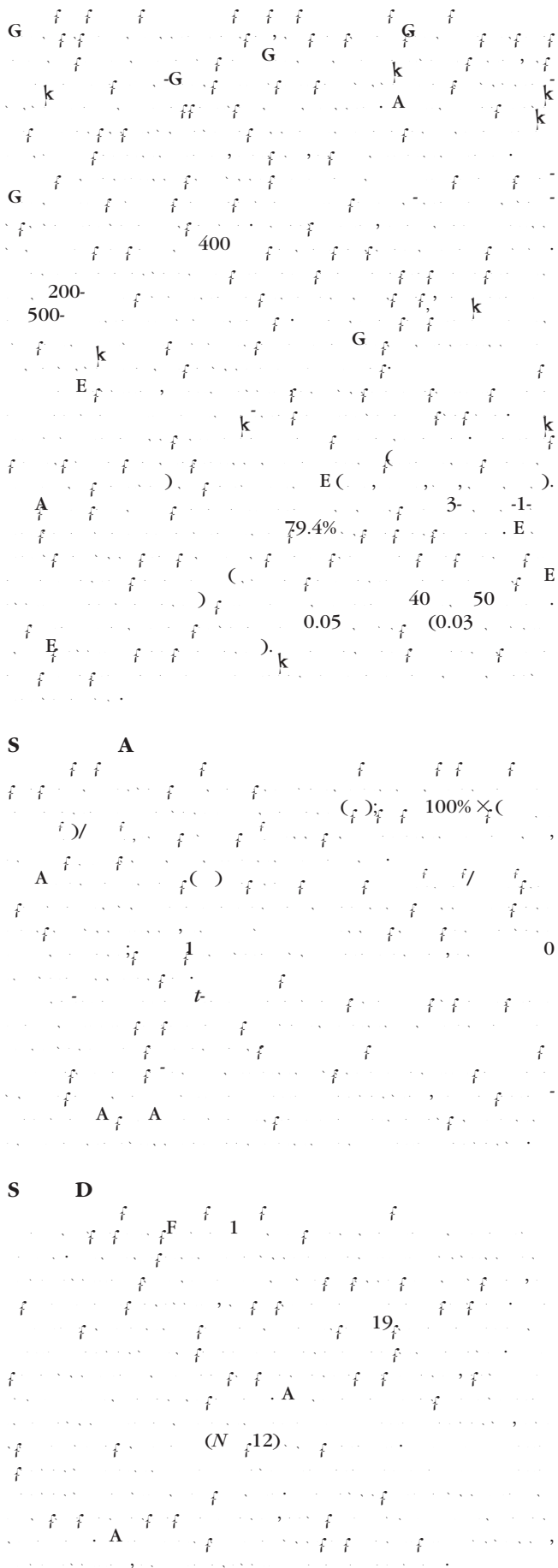
0° 180°
k (17°
2)
k
1.6
G
G (36° 126°)
(F = 4).
80% 2
F A
A E (-E
k
E k (-E
E k
E k (-E
E E (-E
E (-E
E (-E
B

a



b





RESULTS

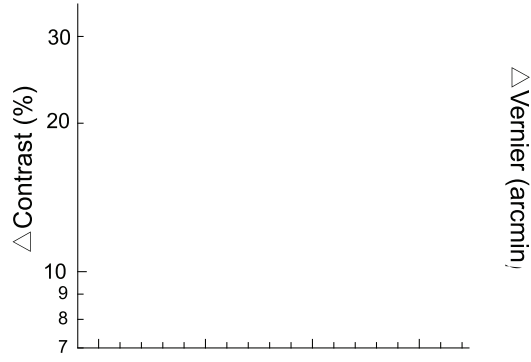
Task Performance

Figure 1 shows the percentage of correct responses for each task across the different conditions. The results show that performance improved significantly over time for all tasks, with the most significant improvements seen in the 'S' and 'A' tasks. The 'S' task showed a significant improvement in performance from 14.9% to 10.4% (ΔC = 2, $P < 0.001$; $F = 2$, 29.3 ± 3.8%, $P < 0.001$; 18.6%, 44.9%). The 'A' task showed a significant improvement in performance from 11.5% to 8.1% (ΔC = 2, $P < 0.001$; $F = 2$, 29.0 ± 2.7%, $P < 0.001$; 18.9%, 38.2%; $F = 2$, 11.3 ± 0.7%, $P = 0.018$; 10.3 ± 0.5%, 20.1%; 0.31 ± 0.09). The 'G' and 'k' tasks showed a significant improvement in performance from 26.7% to 10.4% (ΔC = 2, $P = 0.001$; $F = 2$, 42.5%, 8.9 ± 1.0%, $P = 0.023$; 3.1%, 32.9%). The 'S' and 'D' tasks showed a significant improvement in performance from 22.7% to 7.3% (ΔC = 2, $P = 0.011$; $F = 2$, 35.2%, 16.1 ± 1.8%, $P < 0.001$; 10.7 ± 1.5%, 16.1 ± 1.8%). The 'S' and 'A' tasks showed a significant improvement in performance from 32.5% to 21.5% (ΔC = 2, $P < 0.001$; $F = 2$, 44.7%, 5.9%, $P = 0.41$; 18.1%, 19.1%, 18.1%). The 'S' and 'A' tasks showed a significant improvement in performance from 33.6% to 14.4% (ΔC = 2, $P < 0.001$; $F = 2$, 53.1%, 14.9 ± 1.4%, $P < 0.001$; 10.4 ± 0.9%, 29.3 ± 3.8%, $P < 0.001$; 18.6%, 44.9%, ± 4.5% ($P = 0.59$, $t = 0.04 ± 0.18$, 0.94 ± 0.20, 0.39), 11.5 ± 1.0%, 8.1 ± 0.9% (ΔC = 2, $P < 0.001$; $F = 2$, 29.0 ± 2.7%, $P < 0.001$; 18.9%, 38.2%; $F = 2$, 11.3 ± 0.7%, $P = 0.018$; 10.3 ± 0.5%, 20.1%, 0.31 ± 0.09), 26.7 ± 4.9%, $P = 0.001$; $F = 2$, 42.5%, 8.9 ± 1.0%, $P = 0.023$; 3.1%, 32.9%), 22.7 ± 3.8% ($P = 0.11$, $t = 0.11$).

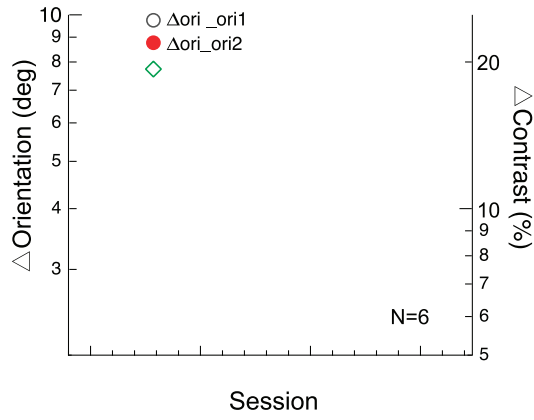
0.81 ± 0.15 , $\Delta C_{\text{p}} = 2$, $40.4 \pm 4.7\%$, $P < 0.001$; $\Delta C_{\text{p}} = 2$, $6.7 \pm 3.3\%$, $P = 0.044$;

(N = 7), E (C, E), A, E.

$13.7 \pm 1.3\%$, $12.6 \pm 1.0\%$

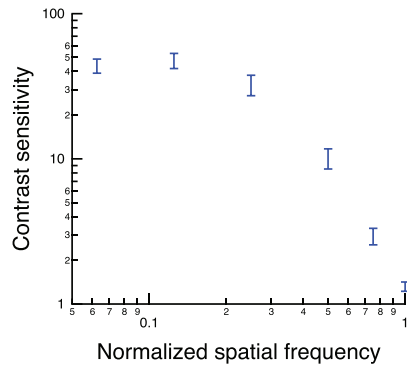


b



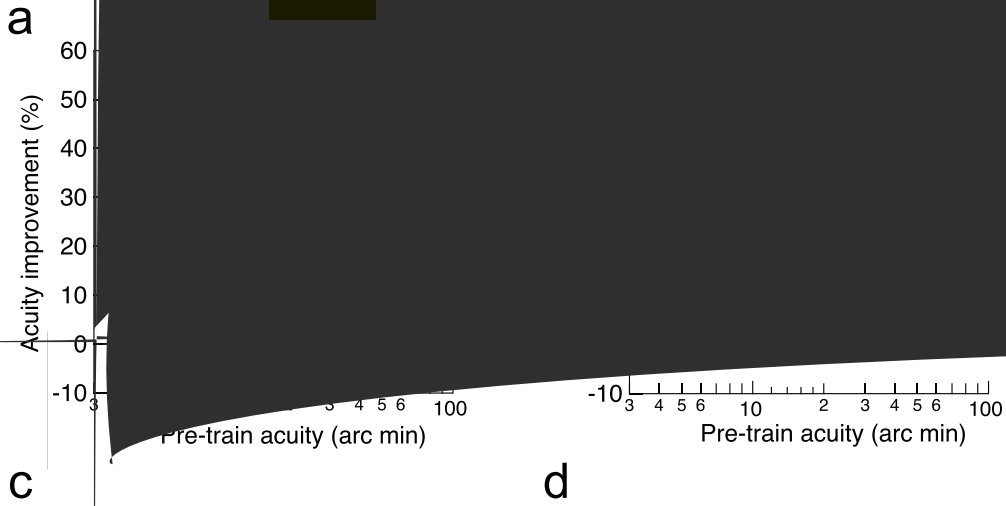
29.5%). $18.0 \pm 4.1\%$, $P = 0.13$, $t = 1.1$.
 ΔC_{ori1} (1) 35.5% , ΔC_{ori2} (2) $18.0 \pm 4.1\%$, $E = 1$.
 0.73 ± 0.19 , $P = 0.13$, $t = 1.1$.
 0.11 . $E = 1$.
 $F = 4$.
 $3.8 \pm 0.6^\circ$ (Δ_{ori1}), $38.8 \pm 4.9\%$, $P = 0.001$, $6.2 \pm 1.1^\circ$.
 28.6% , 58.3% ; $F = 4$.
 8.9% (Δ_{ori2}), $8.3 \pm 5.1\%$, $P = 0.44$.
 6.3% , $P = 0.038$; 10.6% , 31.1% , $14.2 \pm$

(Δ_{ori2}), $5.5 \pm 0.8^\circ$, 10.6% .
 $4.3 \pm 0.3^\circ$, $24.7 \pm 5.3\%$, $P = 0.003$, 11.6% .
 47.9% , $30.6 \pm 6.9\%$, 11.6% .
 52.7% , 0.76 ± 0.13 .
 Δ_{ori1} (1), Δ_{ori2} (2).
 $P = 0.18$, $t = 1.1$.
 $E = 1$.
 $F = 4$.
T I TPE C S,
A S
C S F.
 $28,29$ ($F = 5$).
 15.3 ± 1.0 .



24.9 ± 1.2 ($P < 0.001$).
 $F_{5, 90}$
 $14.93, P = 0.001$,
 $(F_{5, 90} = 7.36, P < 0.001)$.
 $5.30, 31$
 $(F_{1, 16} = 0.55, P = 0.47)$.
 $(F_{1, 16} = 9.54, P = 0.007)$.
 $(F_{1, 16} = 30.45, P < 0.001)$.

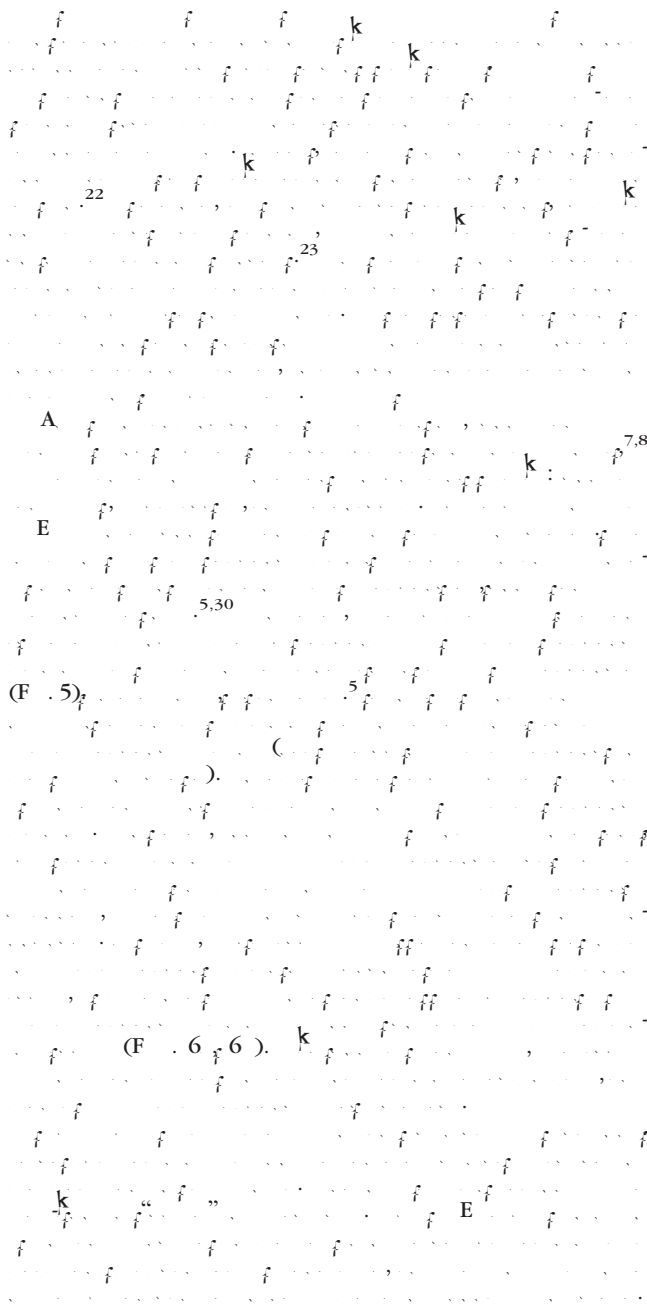
16.2 ± 1.9 , 13.1 ± 1.5 , $16.7 \pm 3.2\%$, $P < 0.001$; $F_{6, 15}$
 24.0 ± 4.8 , 19.5 ± 3.8
 $15.1 \pm 3.2\%$, $P < 0.001$; $F_{6, 15}$
 10.7 ± 2.6
 $14.9 \pm 2.8\%$, $P < 0.001$
 $14.5 \pm 2.9\%$, $P < 0.001$,
 $29.0 \pm 3.8\%$, 13.8% , 52.8%
 $27.0 \pm 4.0\%$, 11.5% , 69.4% , $F_{6, 15}$
 1.6
 12
 $(P = 0.62, t)$.
 1.5 ± 0.2
 $8.4 \pm 2.0\%$ (0.4)
 $(F_{1, 18} = 6.37, P = 0.021)$,
 $(F_{1, 18} = 3.56, P = 0.075)$.
 $(r = 0.33, P = 0.19)$
 $(r = 0.40, P = 0.09)$.
 $(r = 0.65, P = 0.003)$, $(r = 0.69, P = 0.001)$.
 24.1% ($n = 8$)
 35.4% ($n = 14$)
 $(P = 0.053, t)$.
 415.3 ± 44.1
 244.2 ± 32.3 ($39.2 \pm 5.2\%$, $P < 0.001$)
 190.0



± 30.7 ($22.8\% \pm 5.8\%$, $P < 0.001$)
 $53.4\% \pm 5.1\%$, 20.0% , 92.5% (6 ,
 6), F , G ,
 500)
 600) A
 12 / 7
 $(40.5 \pm$
 8.3% , $36.9 \pm 2.3\%$, $P = 0.75$). B
 $(32.0 \pm 7.1\%$, $7.1 \pm 7.1\%$, P
 0.034 ,
 $(r = 0.085$, $P = 0.73)$,
 $(r = 0.32$, $P = 0.35$, n
 11). k
 $(r = 0.38$, $P = 0.11)$,
 $(r = 0.59$, $P = 0.056$, $n = 11)$.

DISCUSSION

E , k , E
 E , E , 23
 k , 23 , $19,20$
 E
 E



SUMMARY

Adult amblyopia is characterized by a loss of visual acuity and contrast sensitivity. Perceptual learning (PL) is a form of experience-dependent plasticity that can improve visual performance in healthy individuals. We investigated whether PL could improve visual performance in adult amblyopes. Amblyopes were trained on a task that required them to identify the orientation of a single 'k' among a background of 'f's. After 10 sessions of PL, amblyopes showed significant improvements in their ability to identify 'k's, as measured by their d-prime (d') values. These improvements were maintained over a 1-month follow-up period. PL also led to changes in the neural responses of the visual cortex, as measured by functional magnetic resonance imaging (fMRI). Specifically, PL led to a decrease in the blood oxygen level dependent (BOLD) signal in the primary visual cortex (V1) when amblyopes performed the task. This decrease in BOLD signal was associated with the improvements in behavioral performance. These findings suggest that PL can improve visual performance in adult amblyopes and that these improvements are associated with changes in the neural responses of the visual cortex.

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