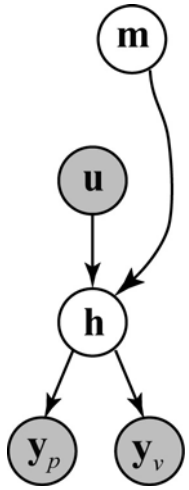
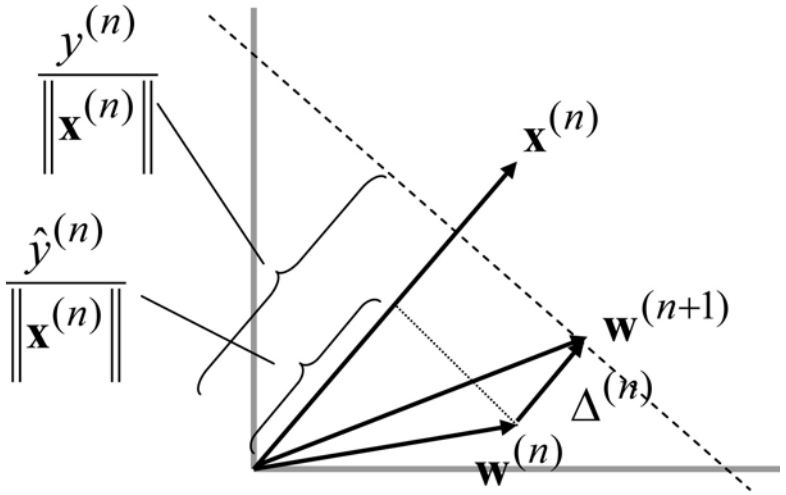
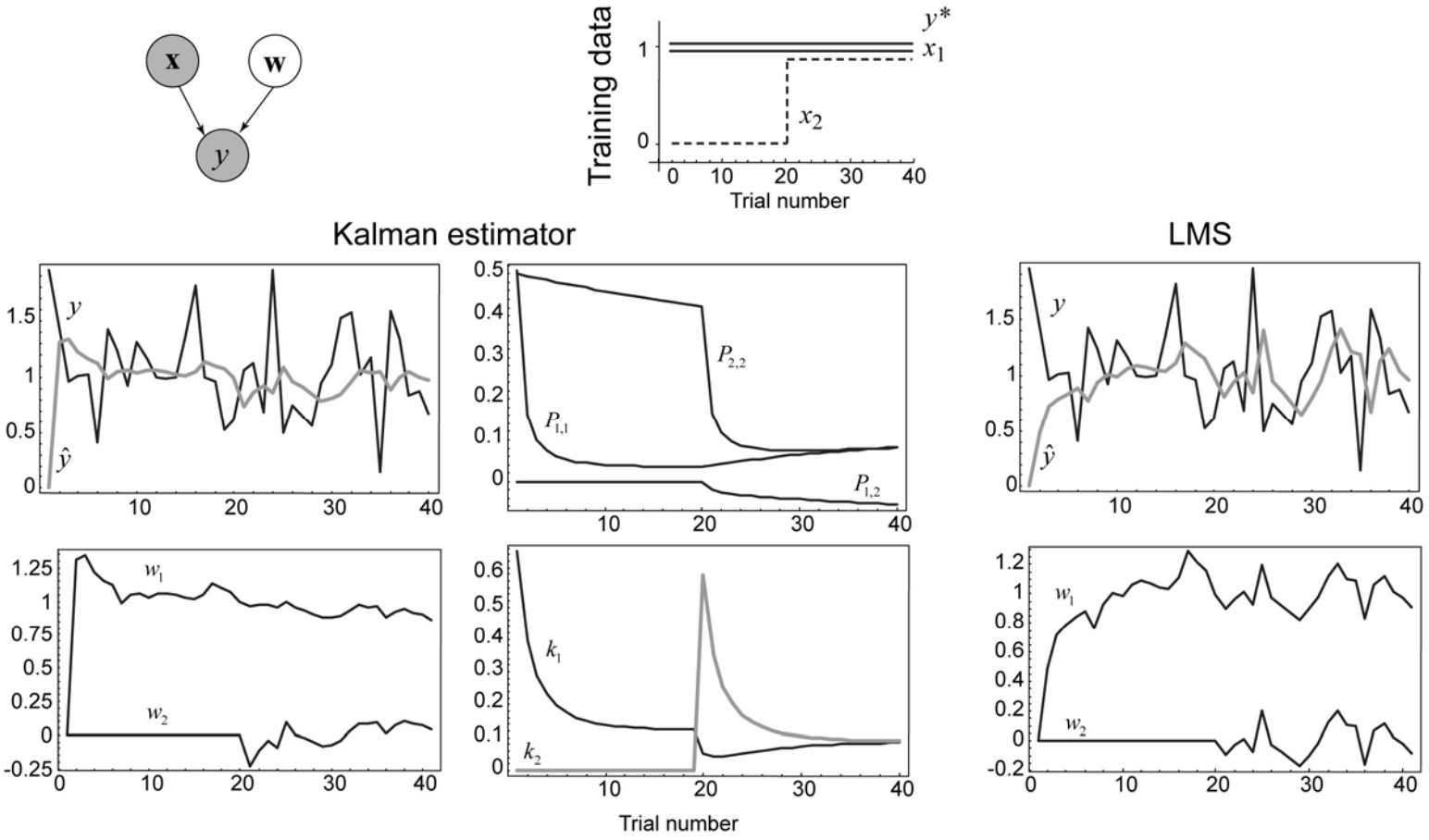
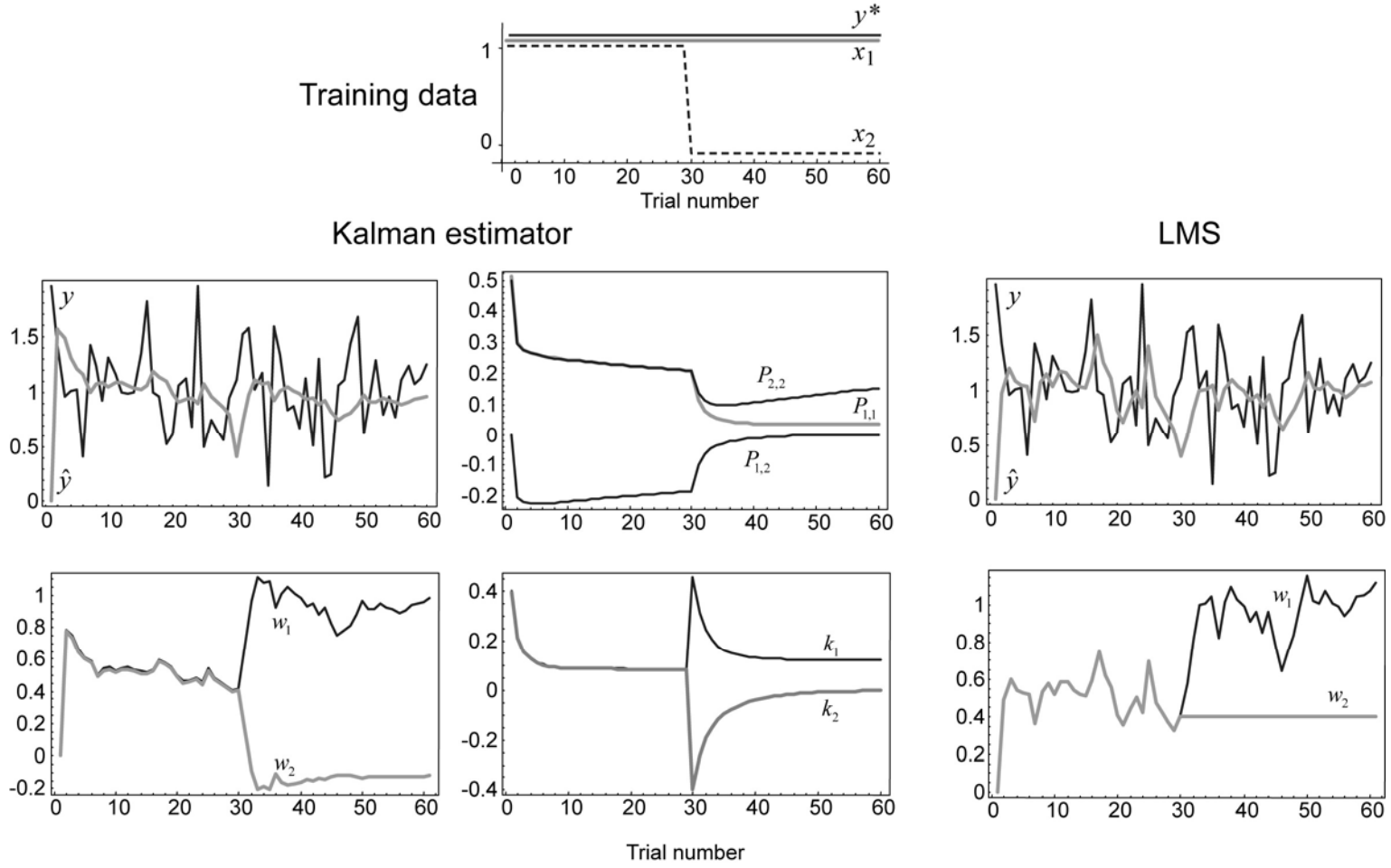
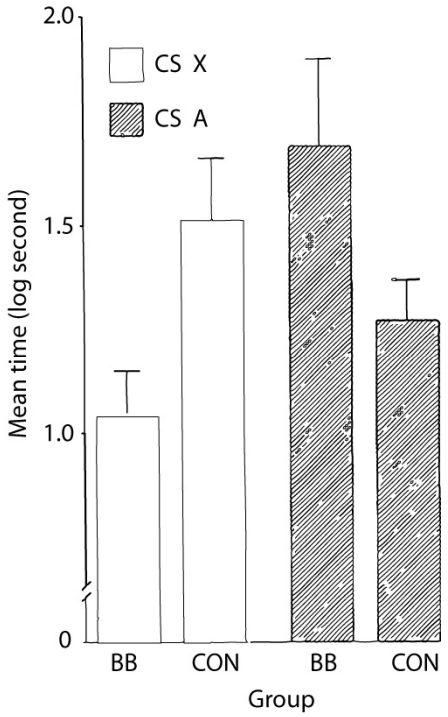

m
u
h
$\mathbf{y}_p$
$\mathbf{y}_v$

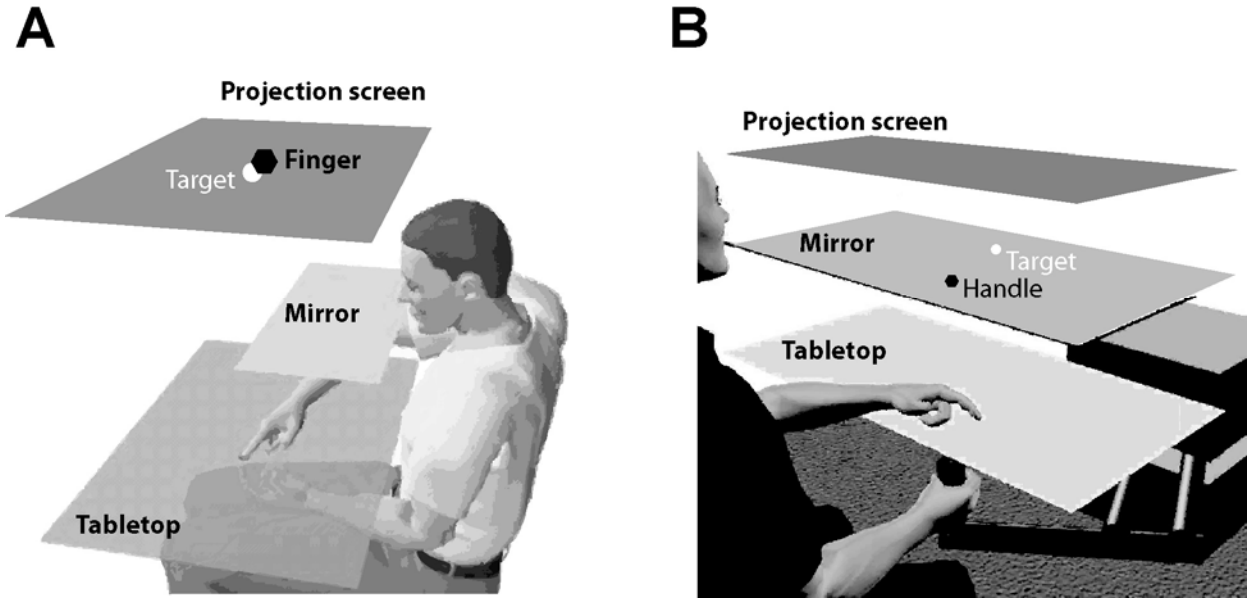

$\frac{y^{(n)}}{\|\mathbf{x}^{(n)}\|}$
$\frac{\hat{y}^{(n)}}{\|\mathbf{x}^{(n)}\|}$
$\mathbf{x}^{(n)}$
$\mathbf{w}^{(n+1)}$
$\Delta^{(n)}$
$\mathbf{w}^{(n)}$

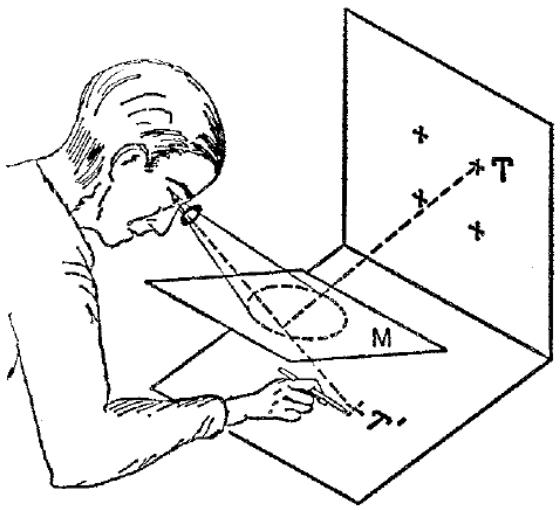

x
w
y
Training data
y*
x1
x2
1
0
0 10 20 30 40
Trial number
Kalman estimator
LMS
y
ŷ
P2,2
P1,1
P1,2
w1
w2
k1
k2
Trial number


Training data
y*
x1
x2
Trial number
Kalman estimator
LMS
y
ŷ
P2,2
P1,1
P1,2
w1
w2
k1
k2
Trial number

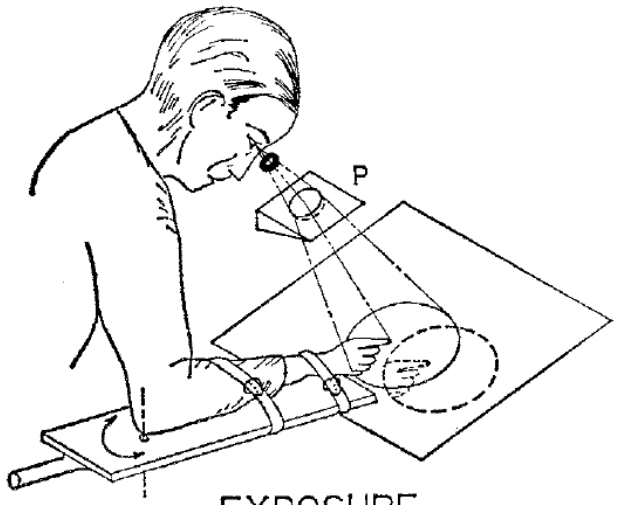
	Treatment			
Group	Phase 1	Phase 2	Phase 3	Tests
Backward blocking	AX -> B	A -> B	B -> US	X? A?
Control	AX -> B	A -> C	B -> US	X? A?



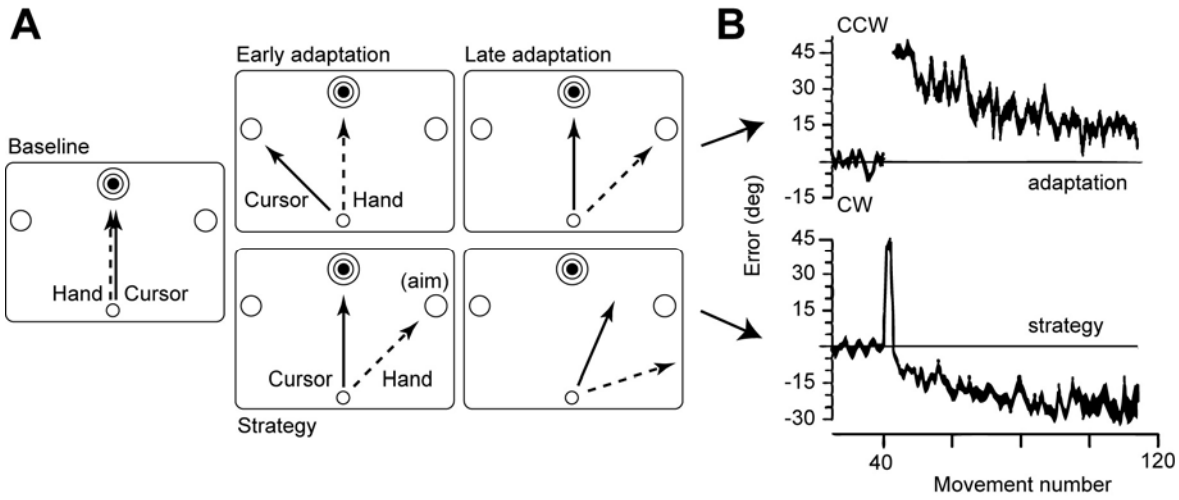

A
Projection screen
Target
Finger
Mirror
Tabletop
B
Projection screen
Mirror
Target
Handle
Tabletop

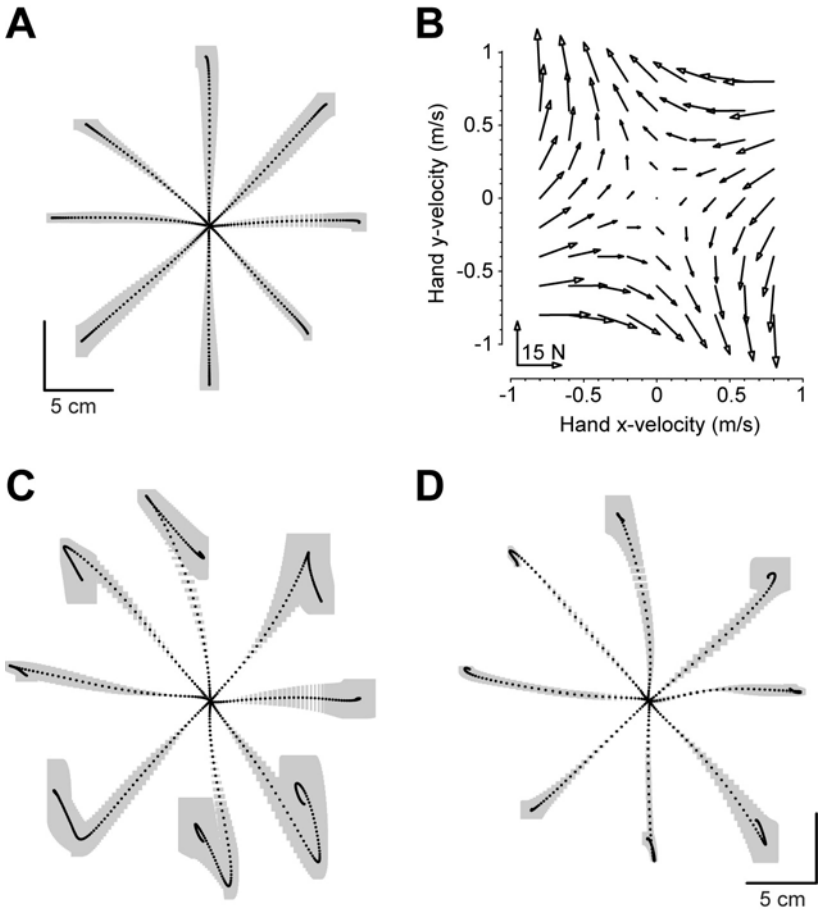


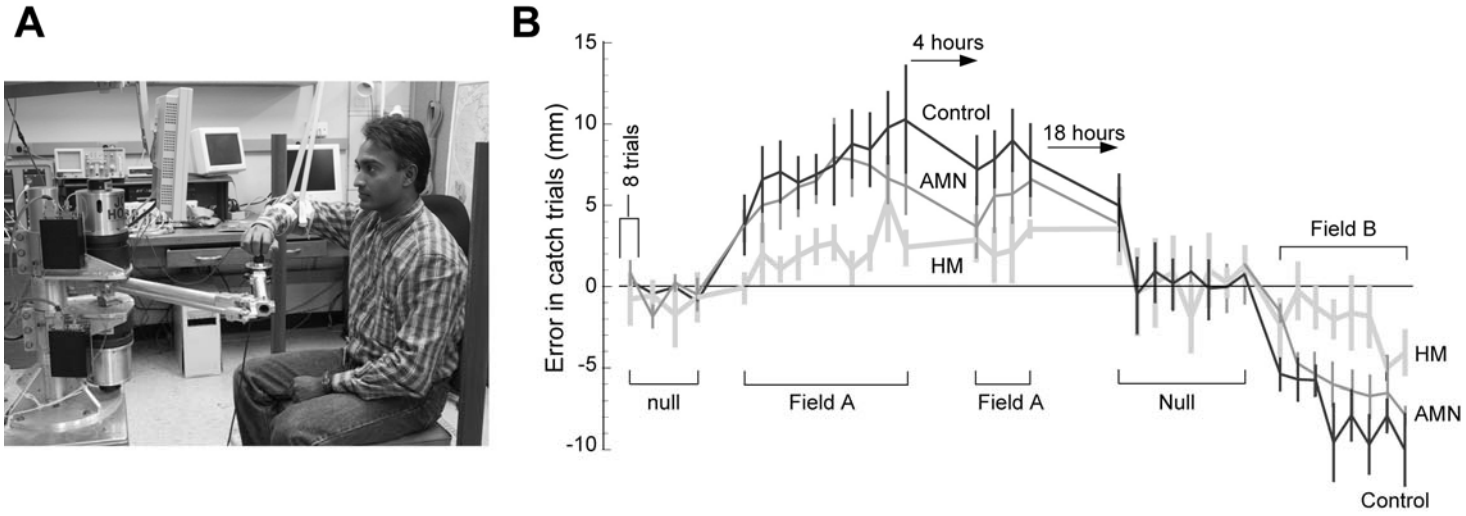
TEST

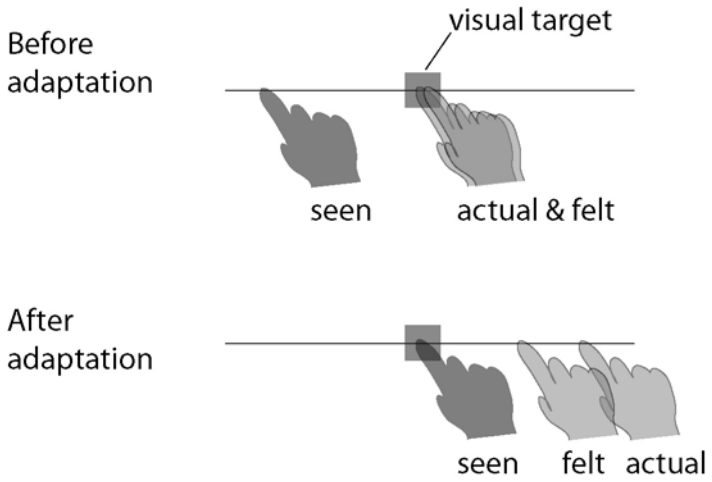


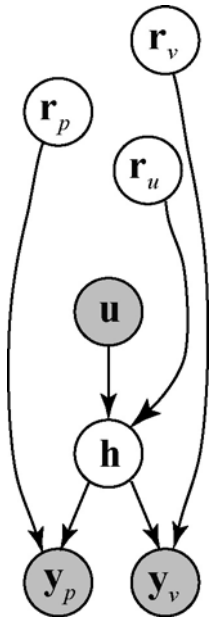
EXPOSURE

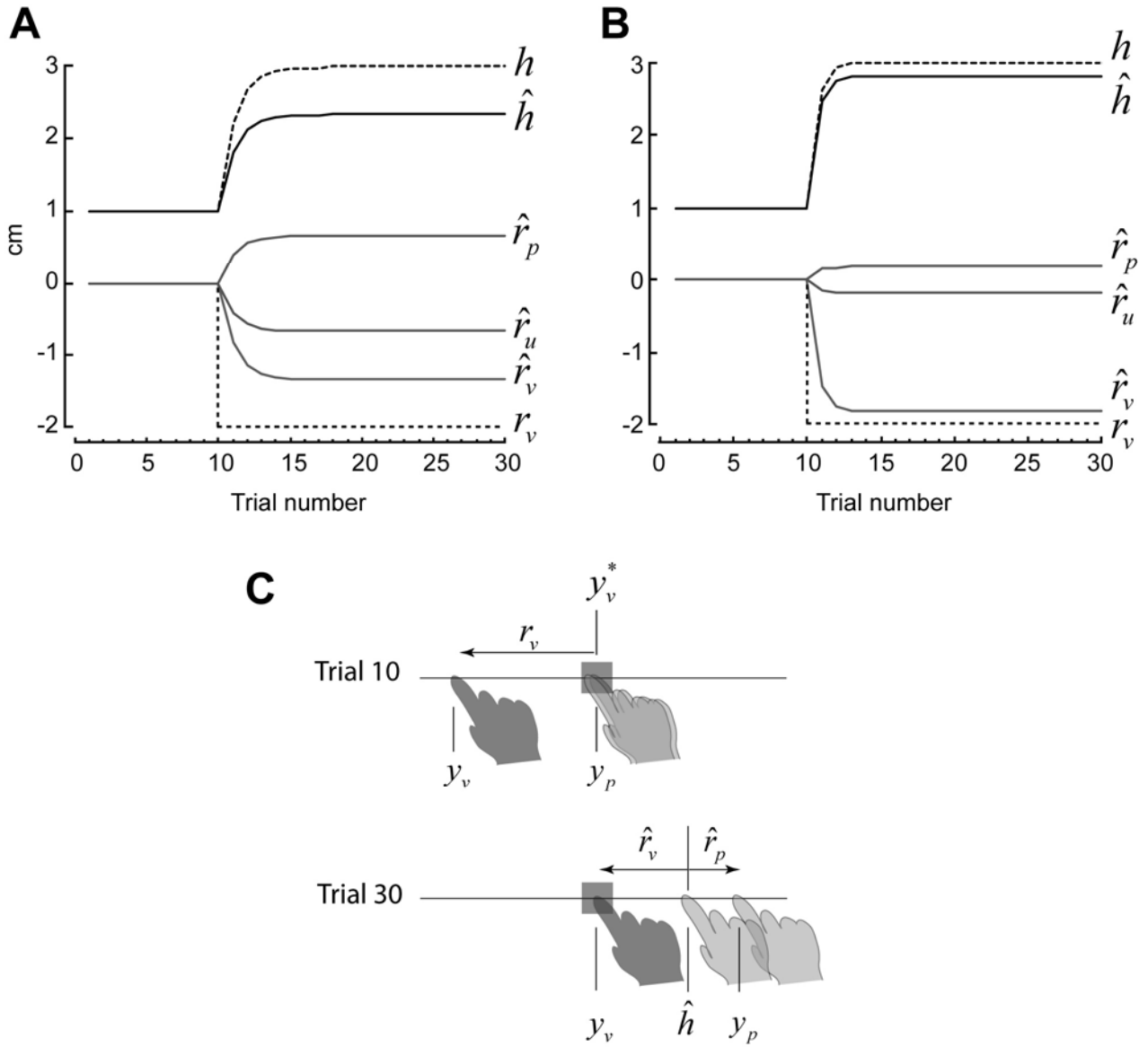

A
Baseline
Hand
Cursor
Early adaptation
Cursor
Hand
Late adaptation
(aim)
Cursor
Hand
Strategy
B
CCW
45
30
15
-15
adaptation
CW
45
30
15
strategy
-15
-30
Error (deg)
40
120
Movement number

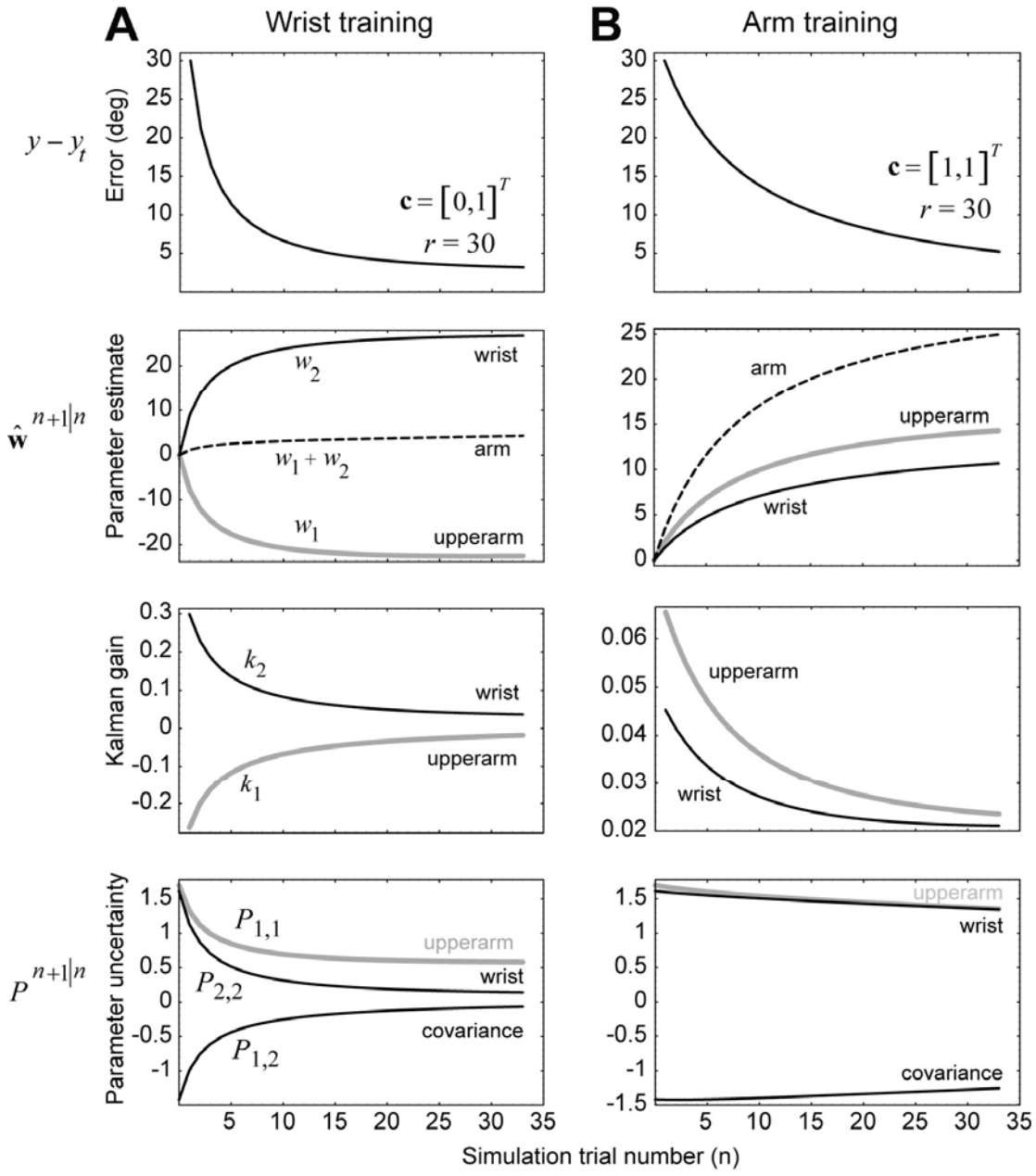

A
5 cm
B
Hand y-velocity (m/s)
1
0.5
0
-0.5
-1
15 N
-1
-0.5
0
0.5
1
Hand x-velocity (m/s)
C
D
5 cm

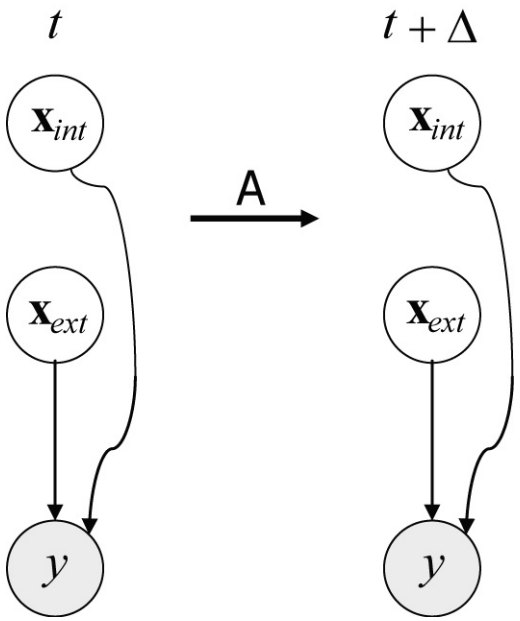

A
B
Error in catch trials (mm)
15
10
5
0
-5
-10
8 trials
4 hours
Control
18 hours
AMN
HM
Field B
null
Field A
Field A
Null
HM
AMN
Control

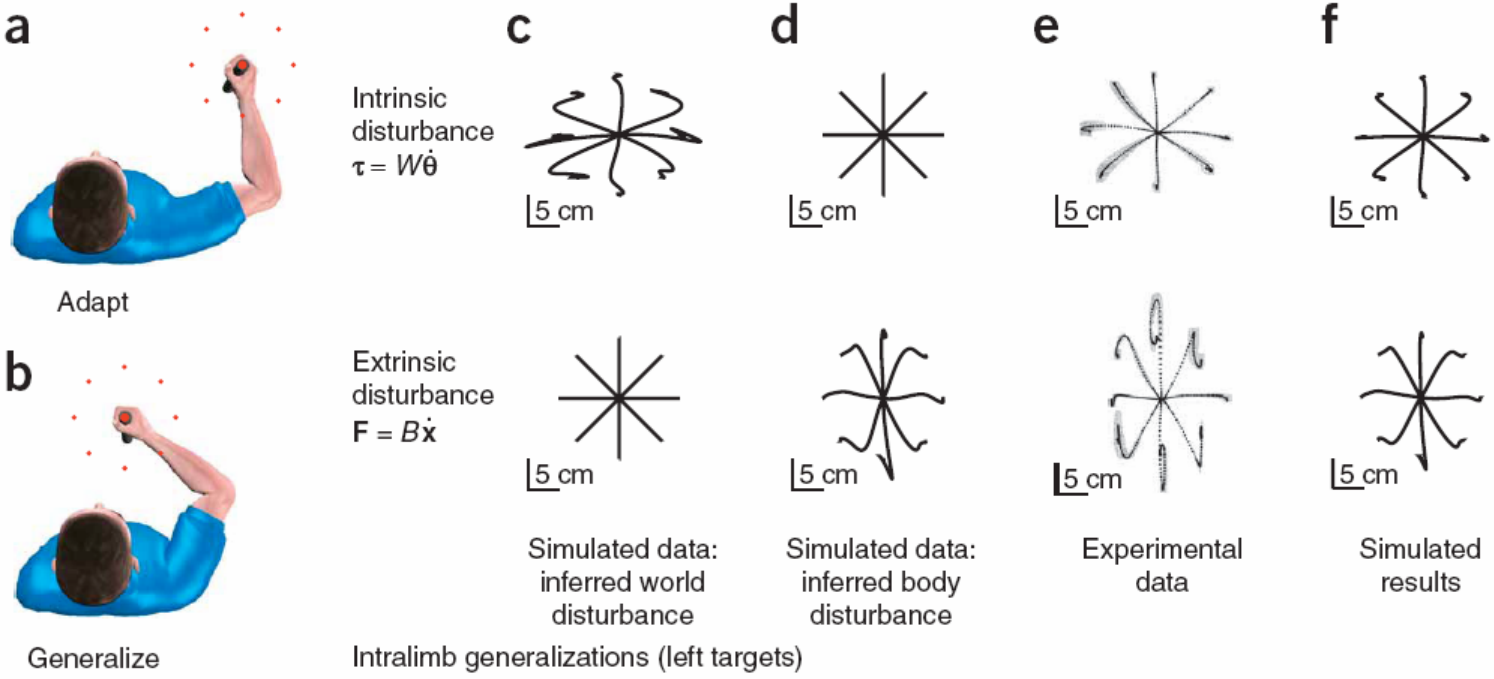

Before
adaptation
visual target
seen
actual & felt
After
adaptation
seen
felt
actual

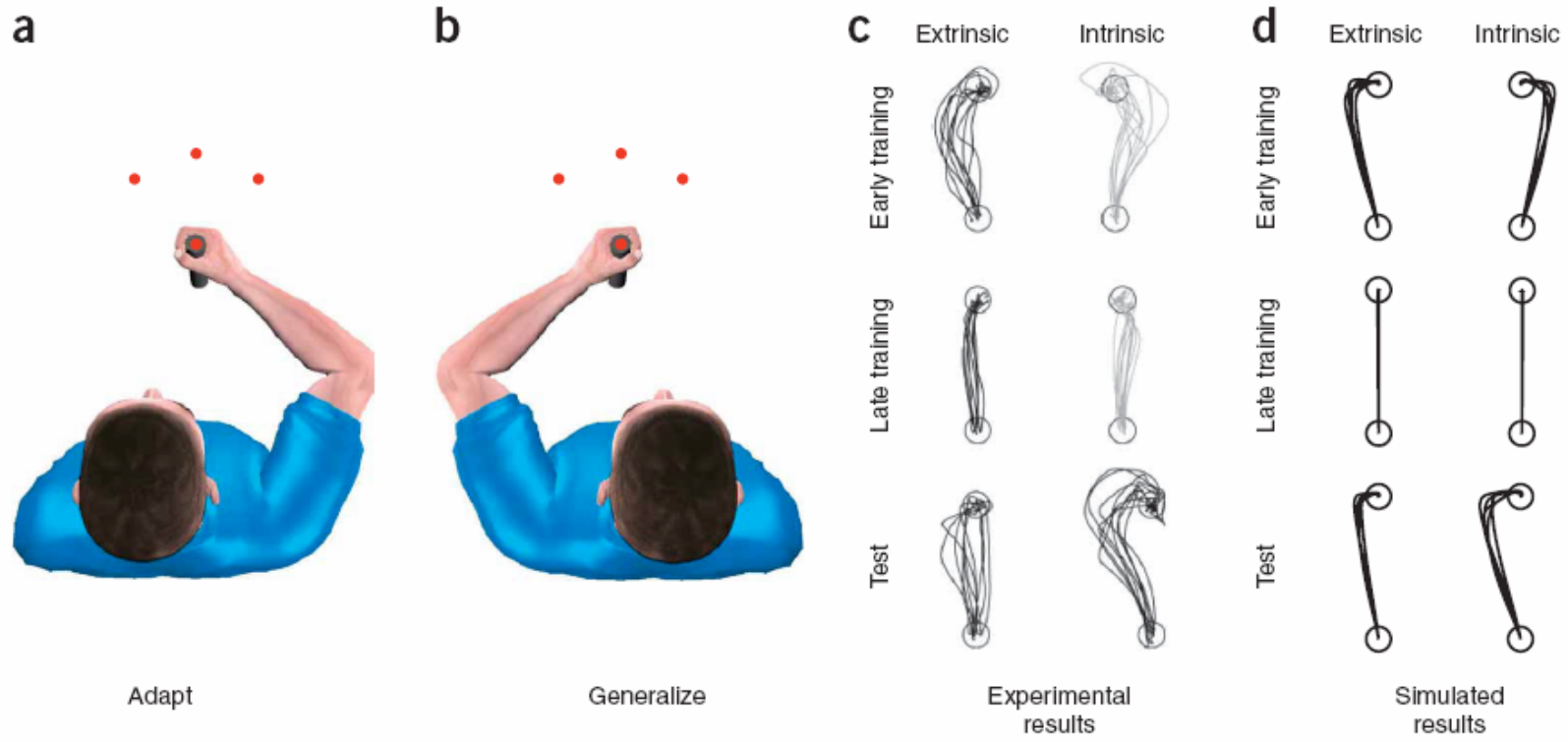

$\mathbf{r}_v$
$\mathbf{r}_p$
$\mathbf{r}_u$
$\mathbf{u}$
$\mathbf{h}$
$\mathbf{y}_p$
$\mathbf{y}_v$

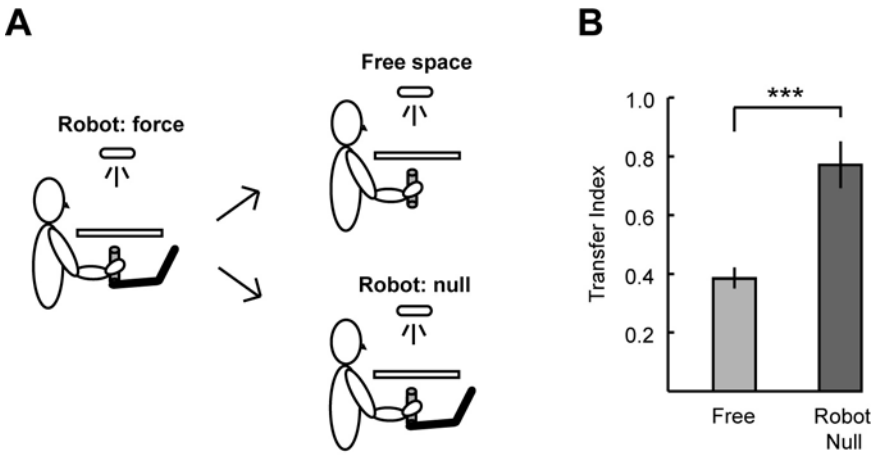

A
B
C
cm
Trial number
Trial 10
Trial 30
h
$\hat{h}$
$\hat{r}_p$
$\hat{r}_u$
$\hat{r}_v$
r_v
y_v^*
y_v
y_p


A
Wrist training
B
Arm training
$y - y_t$
Error (deg)
$\mathbf{c} = [0,1]^T$
$r = 30$
$\mathbf{c} = [1,1]^T$
$r = 30$
$\hat{\mathbf{w}}^{n+1|n}$
Parameter estimate
w_2
wrist
$w_1 + w_2$
arm
w_1
upperarm
arm
upperarm
wrist
Kalman gain
k_2
wrist
upperarm
k_1
upperarm
wrist
$P^{n+1|n}$
Parameter uncertainty
$P_{1,1}$
upperarm
$P_{2,2}$
wrist
covariance
$P_{1,2}$
upperarm
wrist
covariance
Simulation trial number (n)


t
t + Δ
x_int
x_ext
y
A
x_int
x_ext
y


a
b
c
d
e
f
Adapt
Generalize
Intrinsic disturbance
τ = Wθ̇
Extrinsic disturbance
F = Bẋ
5 cm
Simulated data: inferred world disturbance
Simulated data: inferred body disturbance
Experimental data
Simulated results
Intralimb generalizations (left targets)


a
b
c
Extrinsic
Intrinsic
d
Extrinsic
Intrinsic
Early training
Late training
Test
Early training
Late training
Test
Adapt
Generalize
Experimental results
Simulated results


A
Robot: force
Free space
Robot: null
B
Transfer Index
1.0
0.8
0.6
0.4
0.2
***
Free
Robot
Null