MASTERS THESIS PRESENTATION FOR DYLAN ROSE

PERIPHERAL FIXATIONAL STABILITY TRAINING IN INDIVIDUALS WITH HEALTHY VISION

EYE MOVEMENTS

- Human eye movements: always on!

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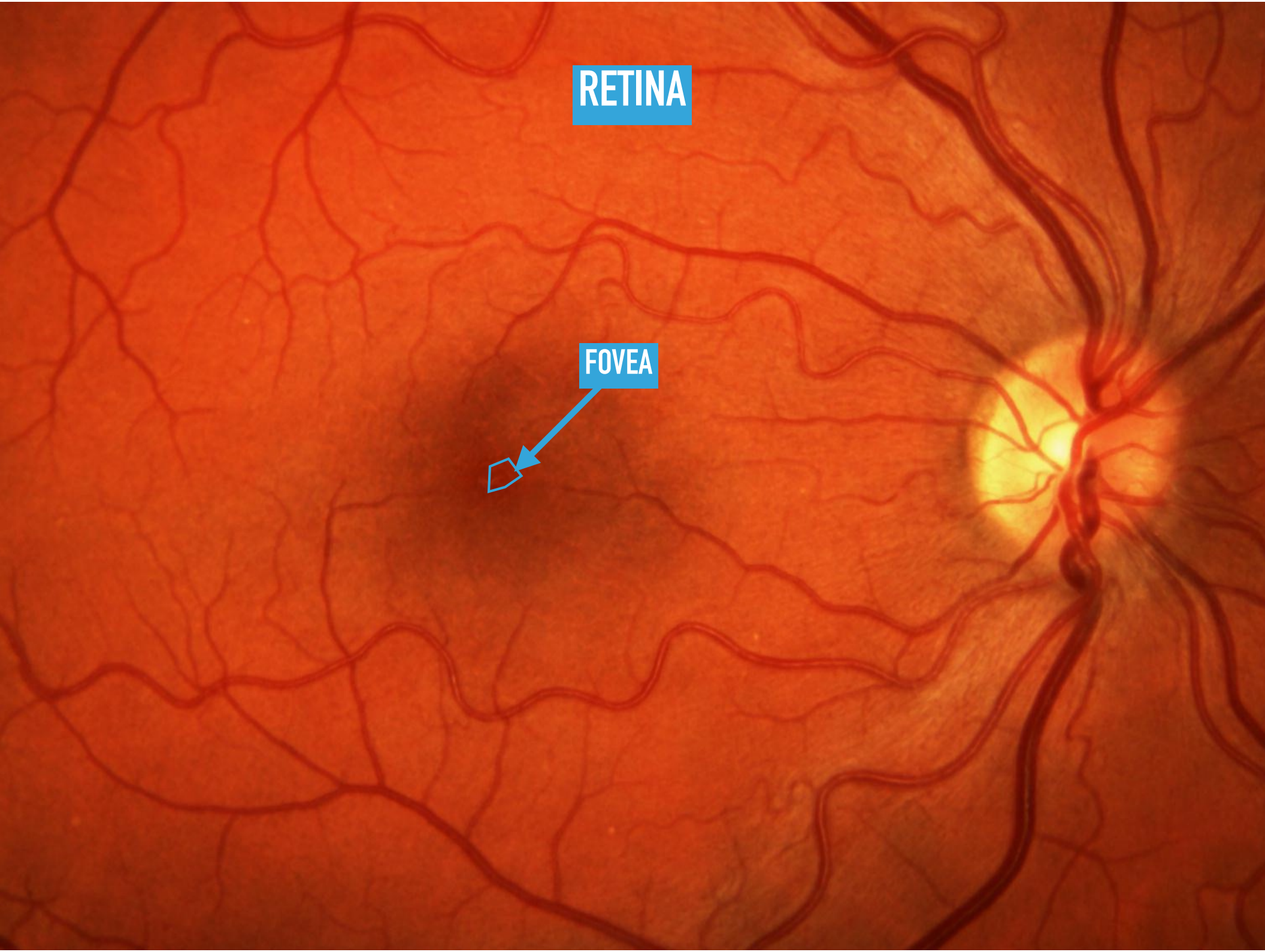
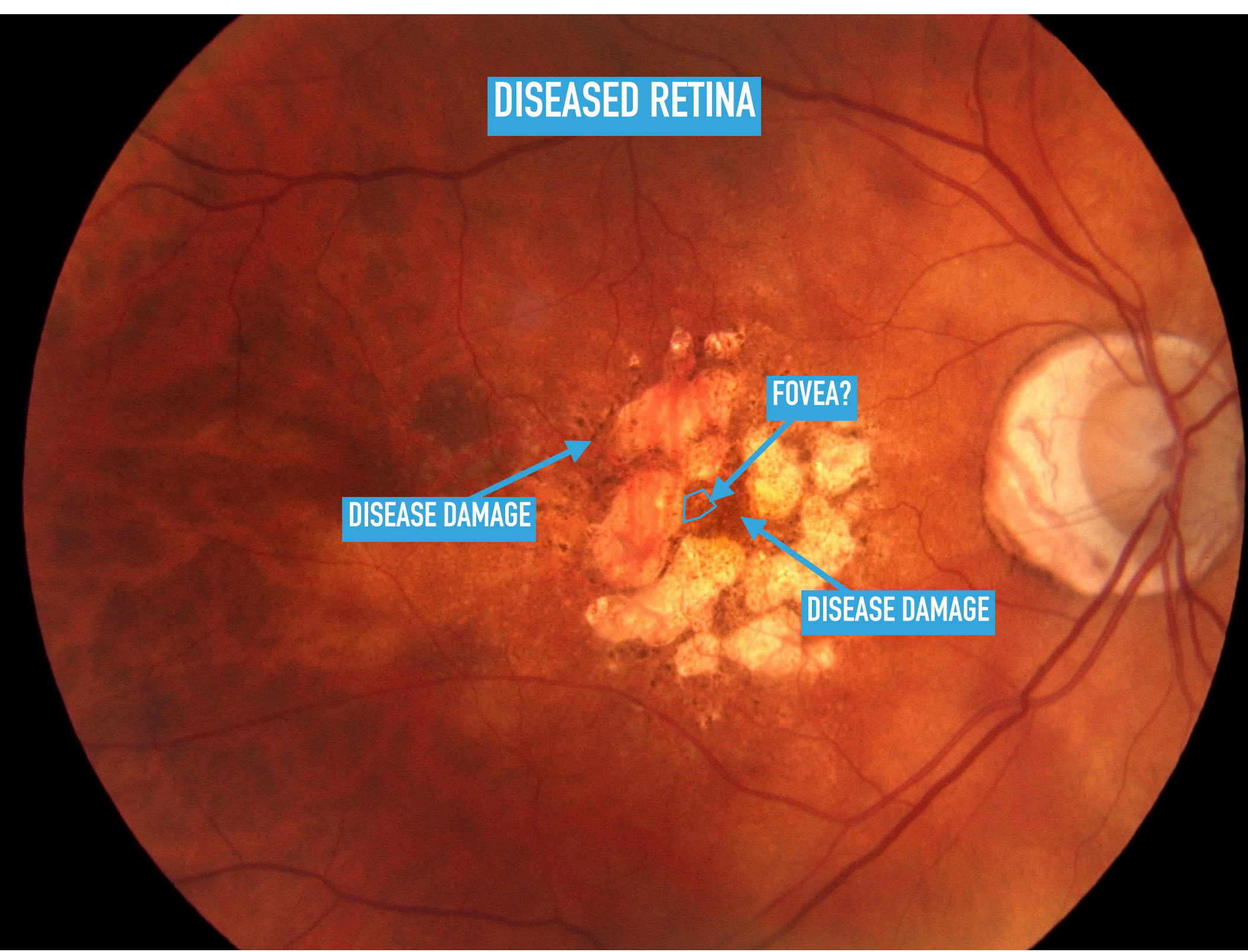
- Used to center region of clearest vision (fovea) over new/ interesting parts of environment, then hold (fixate) to gather information


RETINA
FOVEA

EYE MOVEMENTS

- Human eye movements: always on!
- Used (in part) to center region of clearest vision (the fovea) over new/interesting parts of environment
- But what if this area is damaged by disease?


DISEASED RETINA
FOVEA?
DISEASE DAMAGE
DISEASE DAMAGE

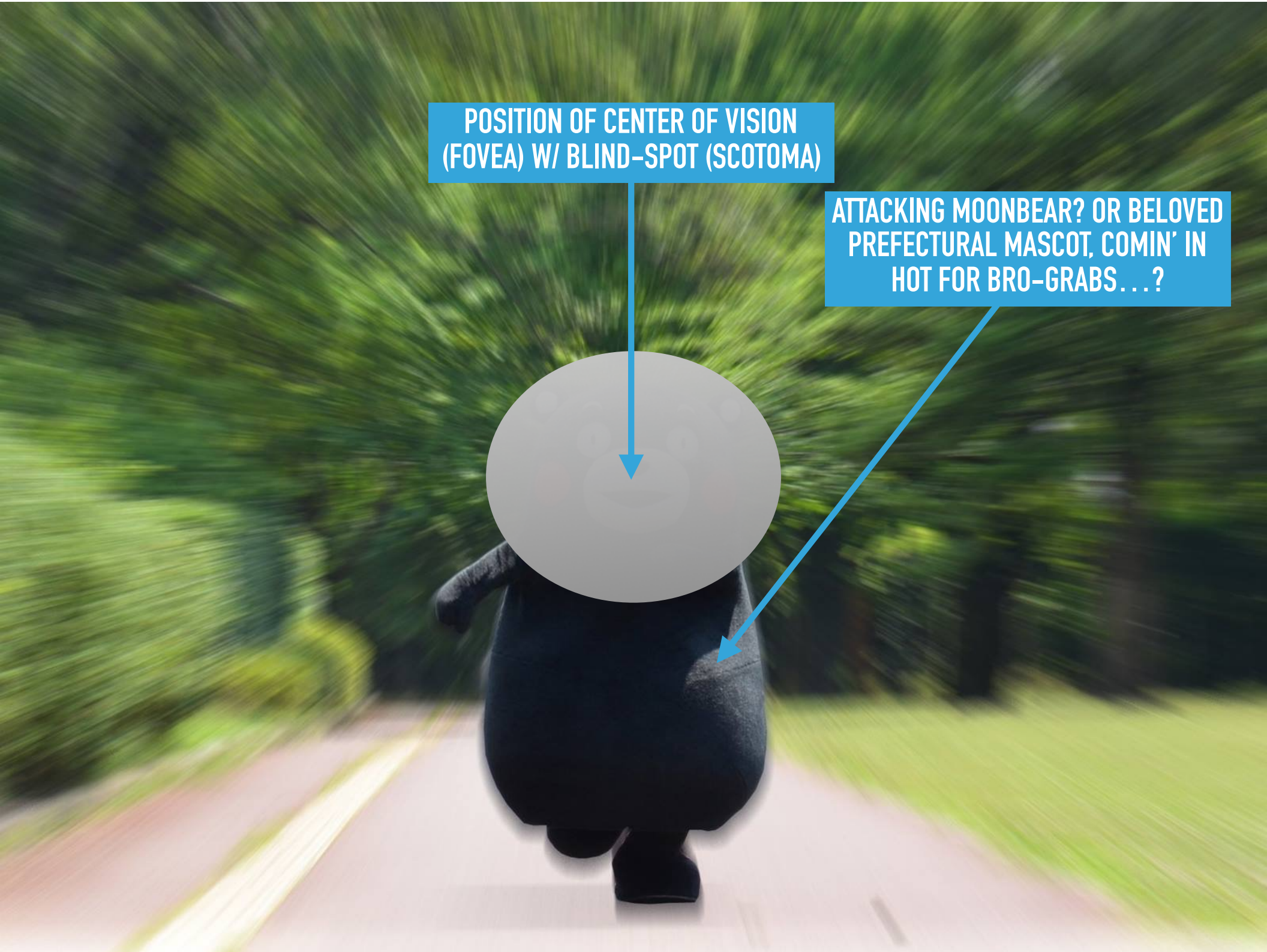
EYE MOVEMENTS

- Human eye movements: always on!
- Used (in part) to center region of clearest vision (the fovea) over new/interesting parts of environment
- But what if fovea (back of eye) is damaged through disease?
- Result: blind spot (scotoma) @ center of vision!

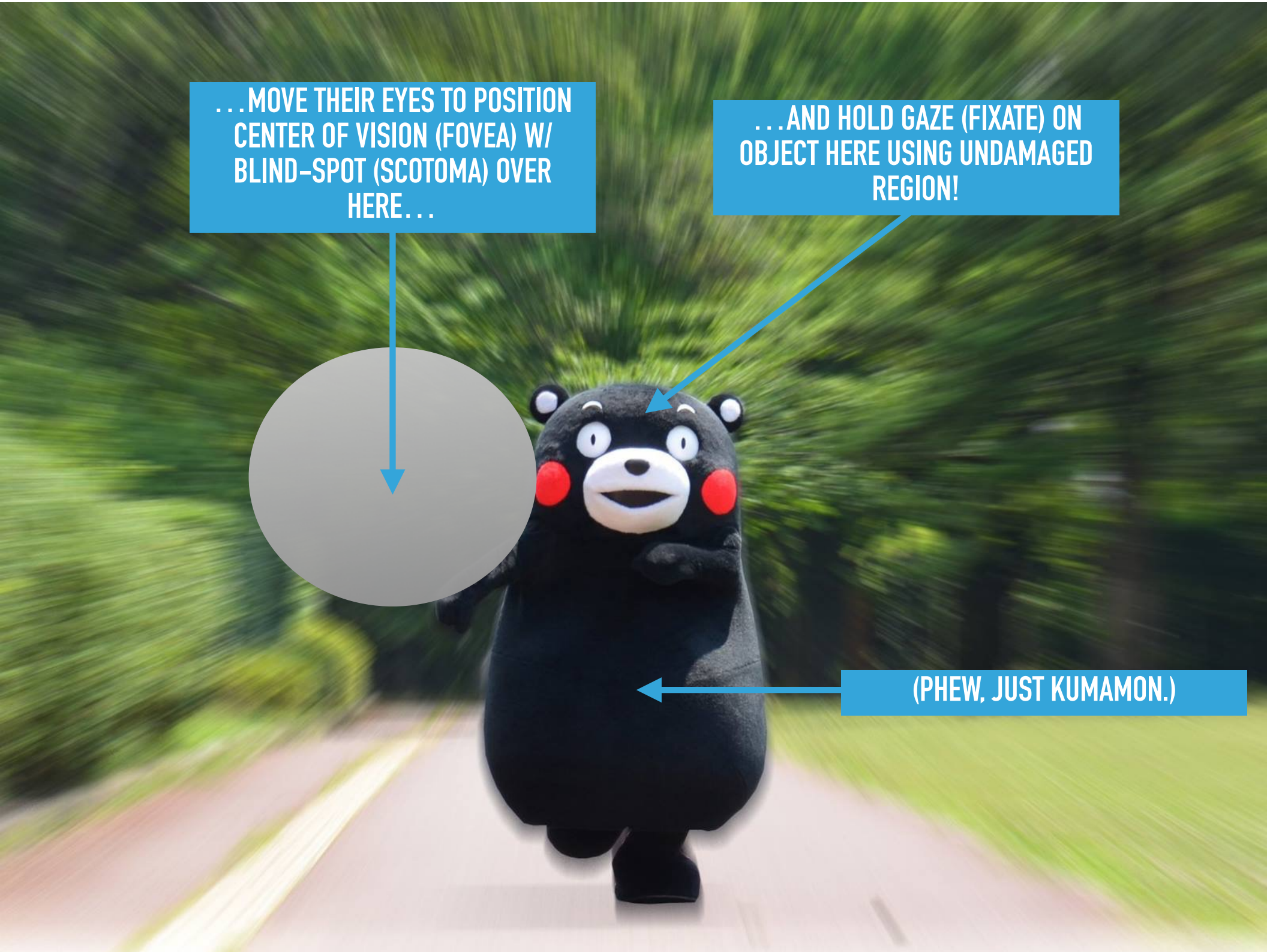
NO BLIND-SPOT (SCOTOMA)

W/ BLIND-SPOT (SCOTOMA)

A MOTIVATING EXAMPLE


POSITION OF CENTER OF VISION
(FOVEA) W/ BLIND-SPOT (SCOTOMA)
ATTACKING MOONBEAR? OR BELOVED
PREFECTURAL MASCOT, COMIN' IN
HOT FOR BRO-GRABS...?

WHAT'S TO BE DONE?
WHAT PATIENTS DO IS. . .


. . . MOVE THEIR EYES TO POSITION CENTER OF VISION (FOVEA) W/ BLIND-SPOT (SCOTOMA) OVER HERE. . .
. . . AND HOLD GAZE (FIXATE) ON OBJECT HERE USING UNDAMAGED REGION!
(PHEW, JUST KUMAMON.)

SOLVED?

NOT SO FAST!

- Problem 1: gaze holding is unstable (“jittery”) outside center of vision (think digital camera “anti-shake”)

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  - What we know: patients get better at this over time
- Problem 2: where do you put the blind-spot?! (stability, clarity vary across back of the eye—may have to trade-off)


. . . AND SACRIFICE VISUAL CLARITY HERE?
PUT BLIND-SPOT HERE. . .
OR PUT BLIND-SPOT HERE. . .
. . . AND SACRIFICE GAZE STABILITY HERE?

NOT SO FAST!

- Problem 1: gaze holding is unstable (“jittery”) outside center of vision (think digital camera “anti-shake”)
  - But patients get better at this over time
- Problem 2: where do you put the blind-spot?! (stability, clarity vary across back of the eye—may have to trade-off)
  - What we know: patients develop“habitual” placement of blind-spot, but where/why unclear

NOT SO FAST!

- Problem 1: gaze holding is unstable ("jittery") outside center of vision (think digital camera "anti-shake")
  - But patients get better at this over time
- Problem 2: where do you put the blind-spot?! (stability, clarity vary across back of the eye—may have to trade-off)
  - Patients develop "habitual" placement of blind-spot, but where/why unclear
- Problem 3: what happens if this habitual placement needs to change in response to disease progression?


. . . THEN YOUR RETINA GETS WORSE. . .
IF YOU DEVELOP A HABIT OF PUTTING YOUR BLIND SPOT HERE. . .
. . . AND YOU HAVE TO MOVE IT HERE. . .
. . . WHAT HAPPENS TO YOUR PERFORMANCE?

NOT SO FAST!

- Problem 1: gaze holding is unstable ("jittery") outside center of vision (think digital camera "anti-shake")
  - But patients get better at this over time
- Problem 2: where do you put the blind-spot?! (stability, clarity vary across back of the eye—may have to trade-off)
  - Patients develop "habitual" placement of blind-spot, but where/why unclear
- Problem 3: what happens if this habitual placement needs to change in response to disease progression?
  - What we know: patients do adapt by shifting habitual blind spot placement

THE BIGGEST PROBLEM

- Bad news: these things are hard to study in the wild! Lots of problems with available data… (mostly for technological reasons)
- Our question: *can we model these phenomena by training healthy controls to do all this?*

OUR OBJECTIVES

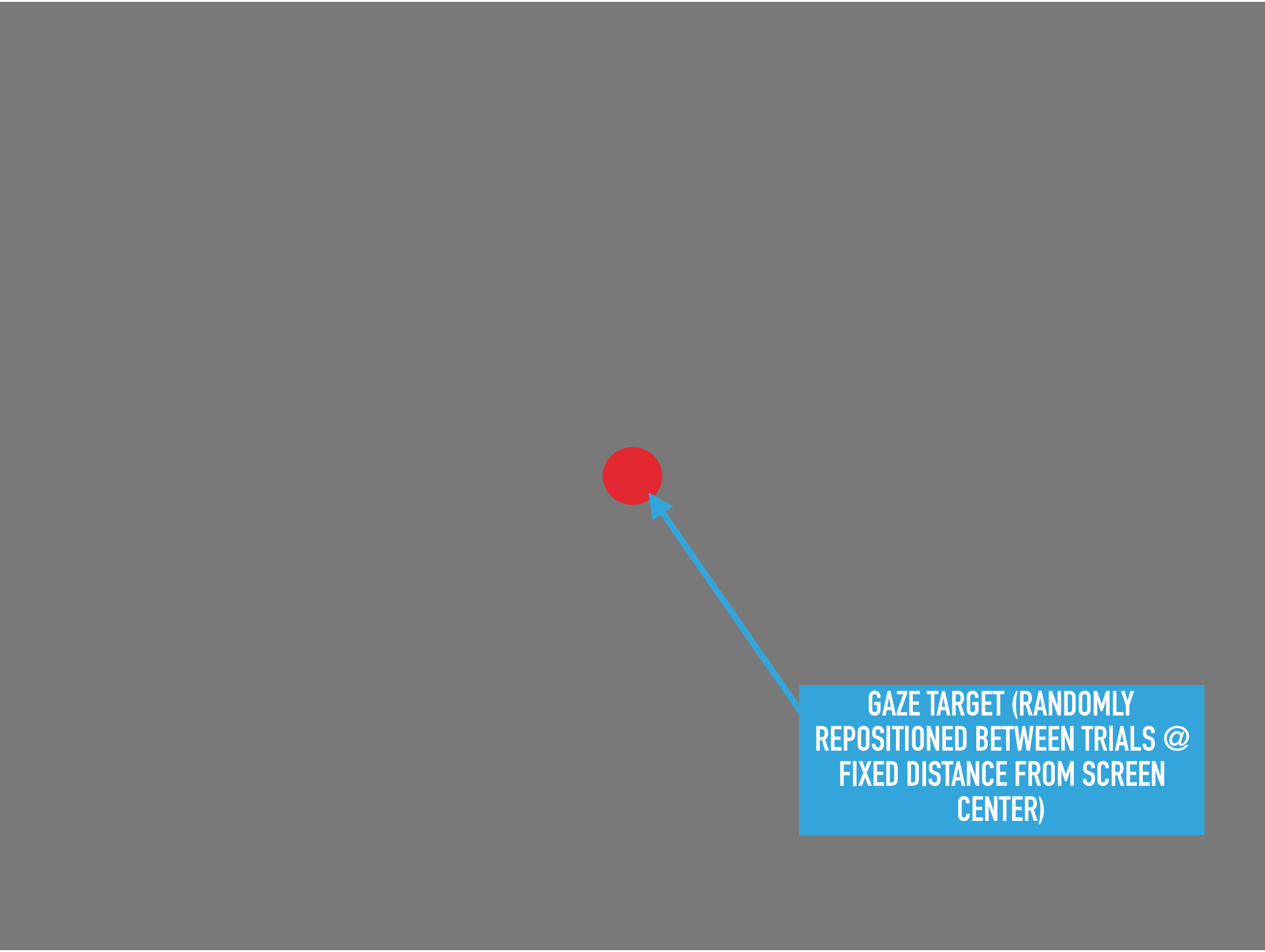
USE HEALTHY CONTROLS TO PROBE WHETHER:

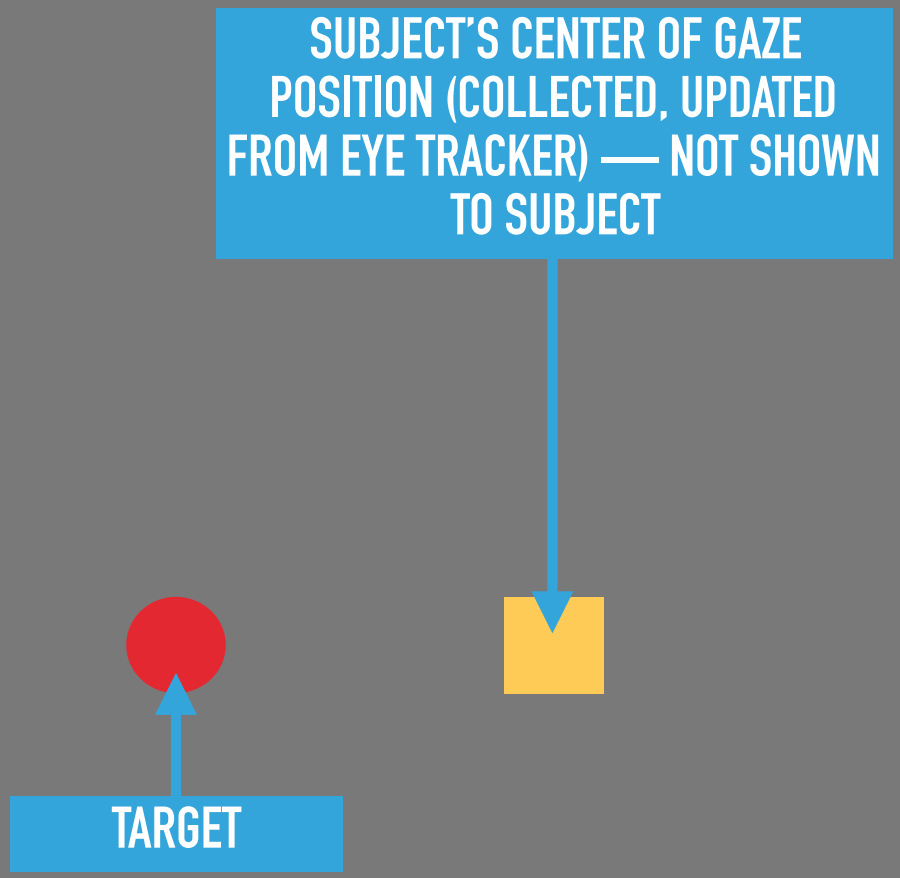
1. fixation stability outside center of vision can be improved with training?
2. distance/orientation of training site relative to center of vision affects performance?
3. training effect persists between training sessions, changes in orientation/distance of training site?
4. training with explicit feedback accelerates learning?

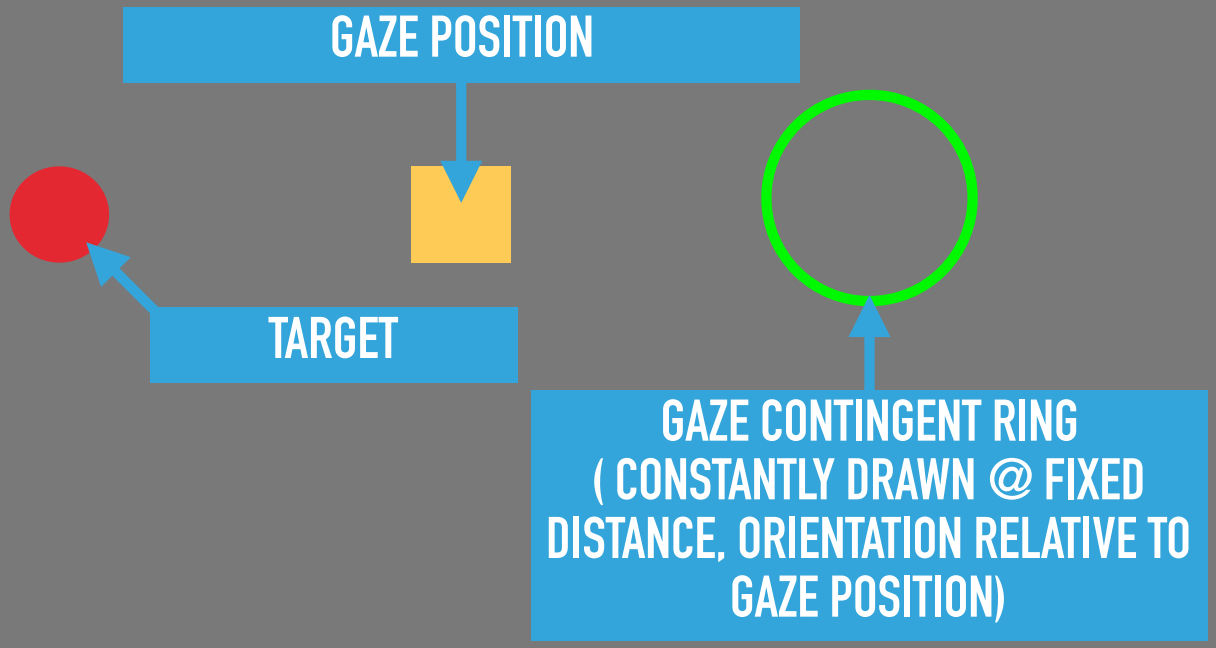
OUR METHODS

APPROACH

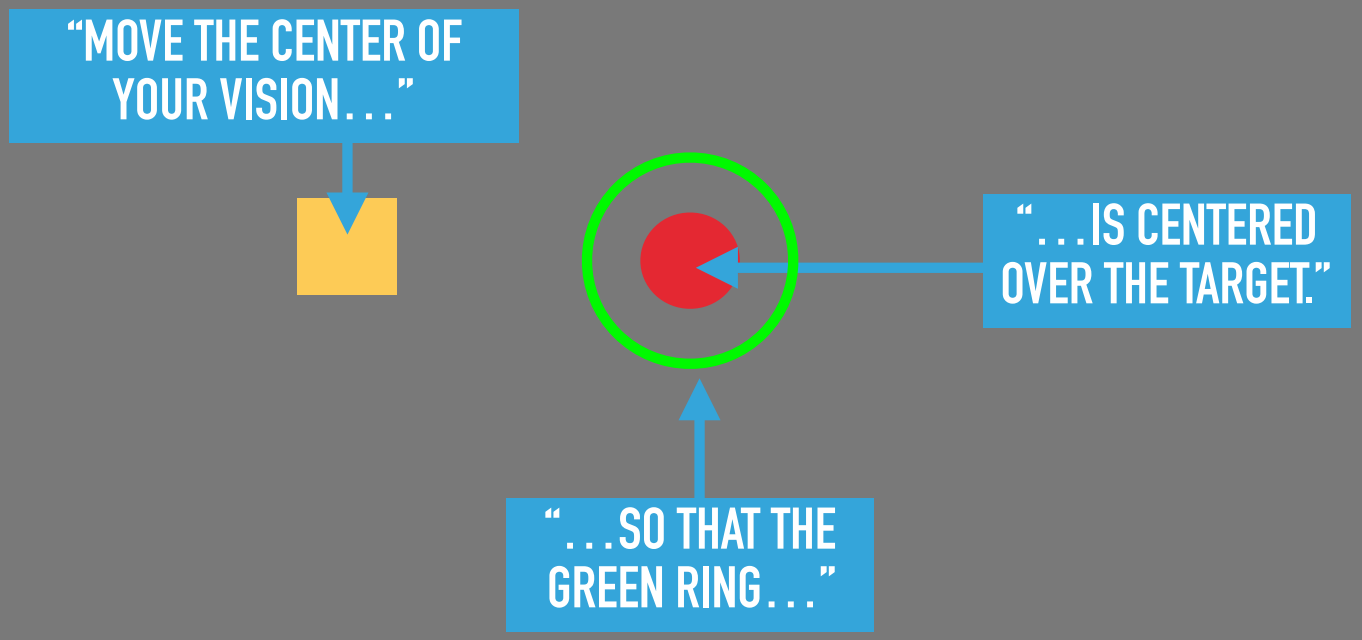
- Simulate central blind spot using eye tracking, track adaptation as f(X) of peripheral gaze stability over time
- Provide real-time gaze stability performance feedback


GAZE TARGET (RANDOMLY REPOSITIONED BETWEEN TRIALS @ FIXED DISTANCE FROM SCREEN CENTER)


SUBJECT'S CENTER OF GAZE POSITION (COLLECTED, UPDATED FROM EYE TRACKER) — NOT SHOWN TO SUBJECT
TARGET

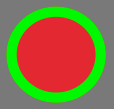

GAZE POSITION
TARGET
GAZE CONTINGENT RING
(CONSTANTLY DRAWN @ FIXED DISTANCE, ORIENTATION RELATIVE TO GAZE POSITION)

THE TASK:


"MOVE THE CENTER OF YOUR VISION..."
"...IS CENTERED OVER THE TARGET."
"...SO THAT THE GREEN RING..."

THE TASK:

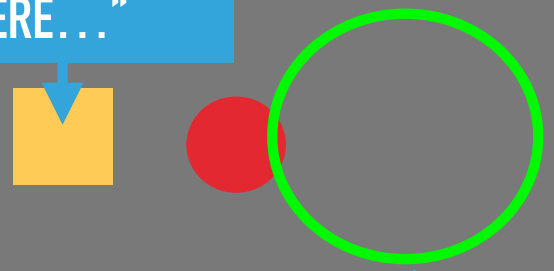
"AS YOU HOLD THIS POSITION..."



"...THE GREEN RING WILL GET SMALLER."

THE TASK:

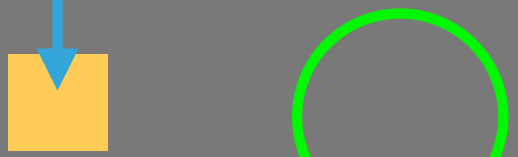
"IF YOU MOVE YOUR CENTER OF VISION AWAY FROM THERE. . ."



". . .THE GREEN RING WILL GET BIGGER."

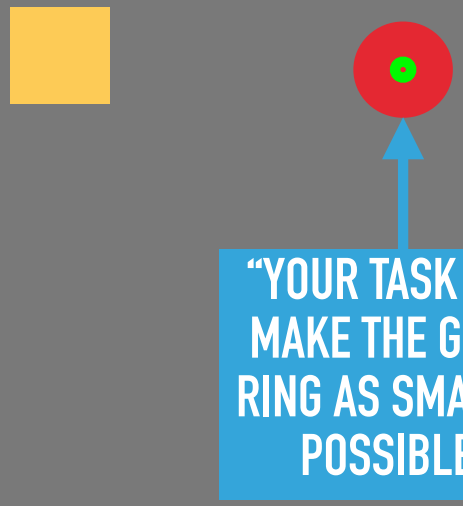
THE TASK:

"IF YOU GET TOO CLOSE TO PUTTING YOUR CENTER OF VISION OVER THE TARGET . . ."



". . . IT'LL BE REMOVED FROM THE DISPLAY."

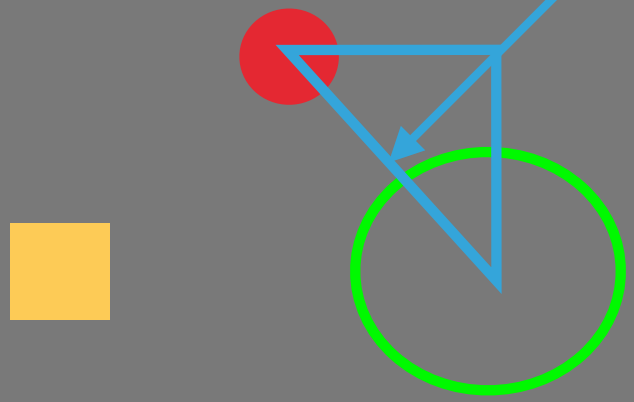
THE TASK:



"YOUR TASK IS TO MAKE THE GREEN RING AS SMALL AS POSSIBLE!"

PERFORMANCE ASSESSED BY:

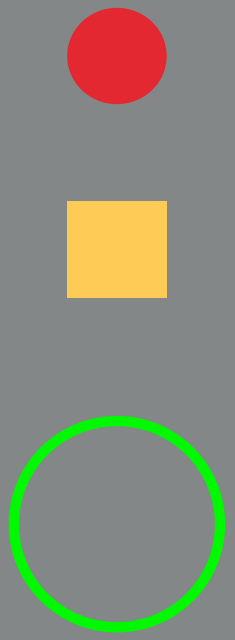
RING/TARGET CENTER EUCLIDEAN DISTANCE



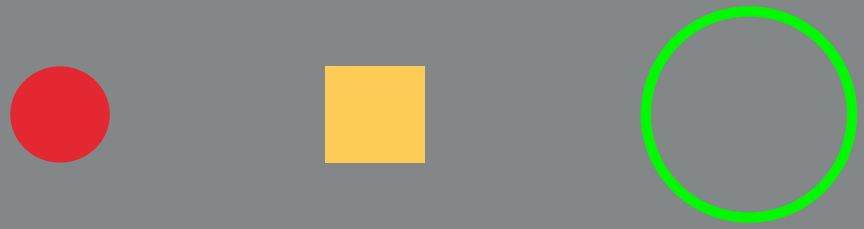
TWO EXPERIMENTS

EXPERIMENT 1: EFFECTS OF ORIENTATION, ORIENTATION ORDER

CONDITION 1: RING IS DRAWN 6.4 DEG BELOW (SOUTH) OF GAZE POSITION



CONDITION 2: RING IS DRAWN 6.4 DEG. RIGHT (EAST) OF GAZE POSITION



2 TRAINING SESSIONS, 200 TRIALS EACH (SPLIT INTO 4 BLOCKS OF 50), SEPARATED BY ~1 WEEK, ORDER COUNTERBALANCED BETWEEN (8) SUBJECTS

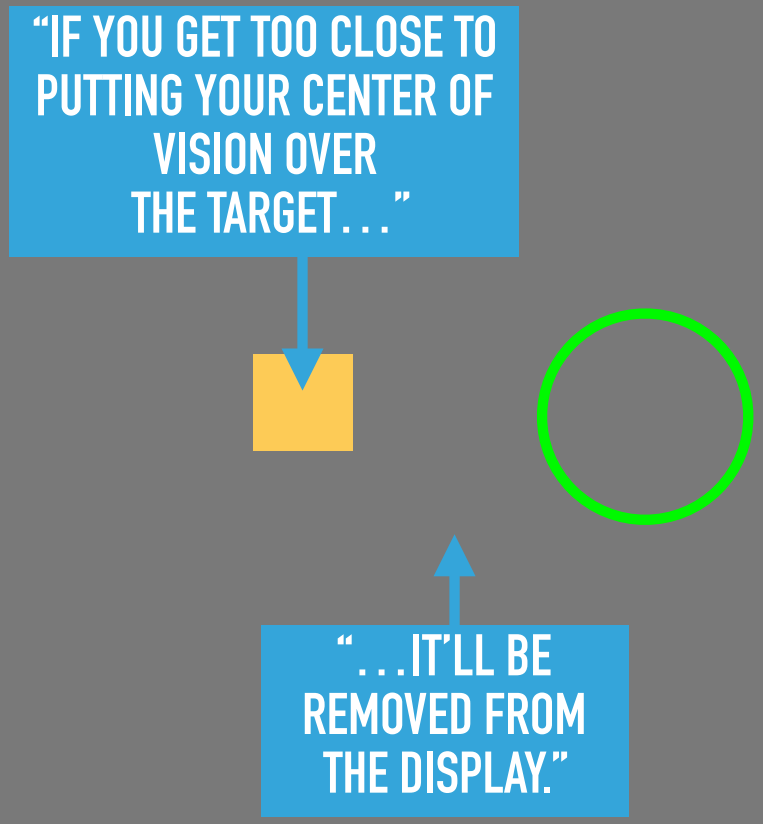
EXPERIMENT 2: EFFECTS OF DISTANCE, DISTANCE ORDER

CONDITION 1: RING IS DRAWN 6.4 DEG (NEAR) TO RIGHT OF GAZE POSITION

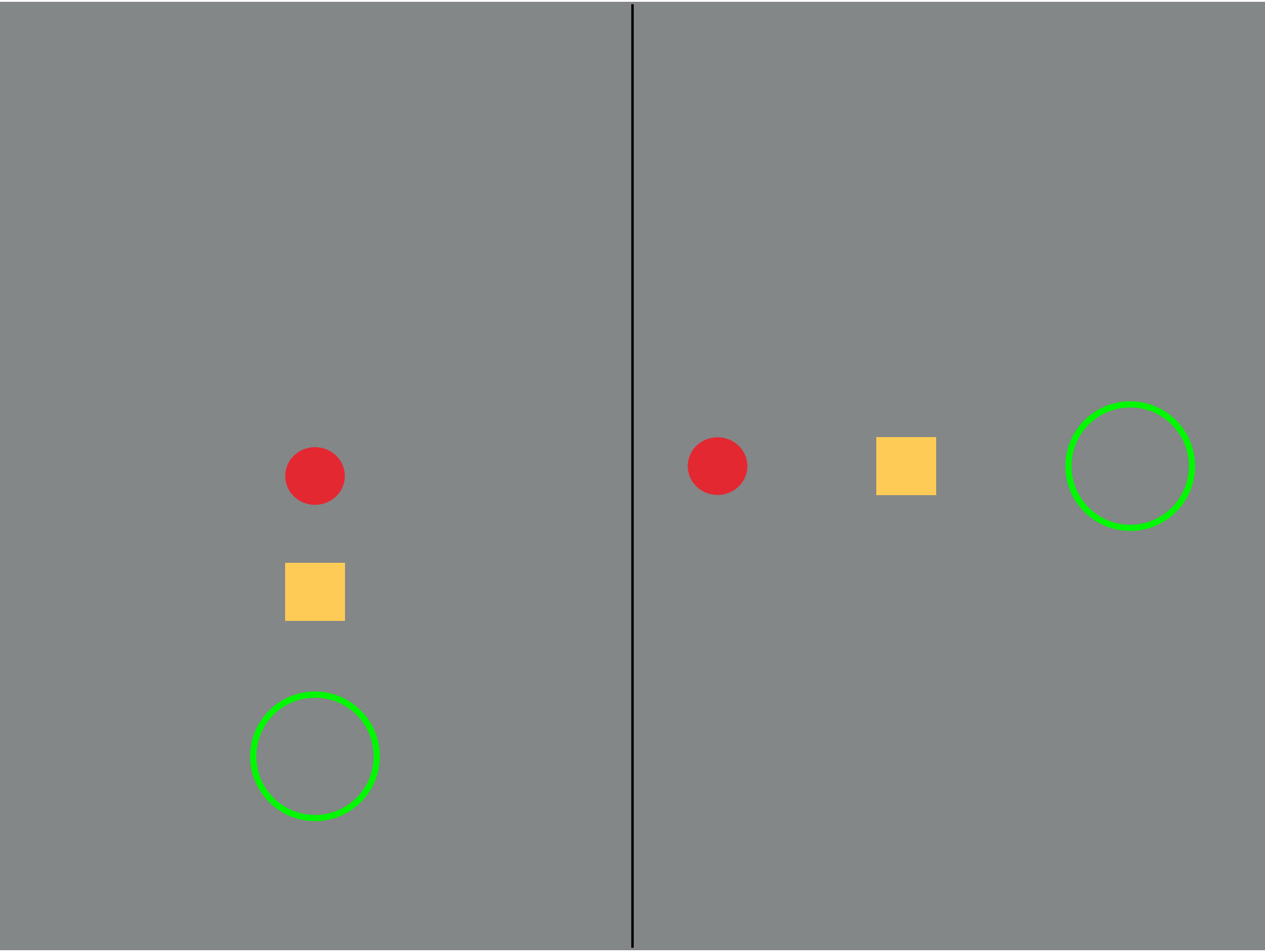
CONDITION 2: RING IS DRAWN 12.8 DEG (FAR) TO RIGHT OF GAZE POSITION

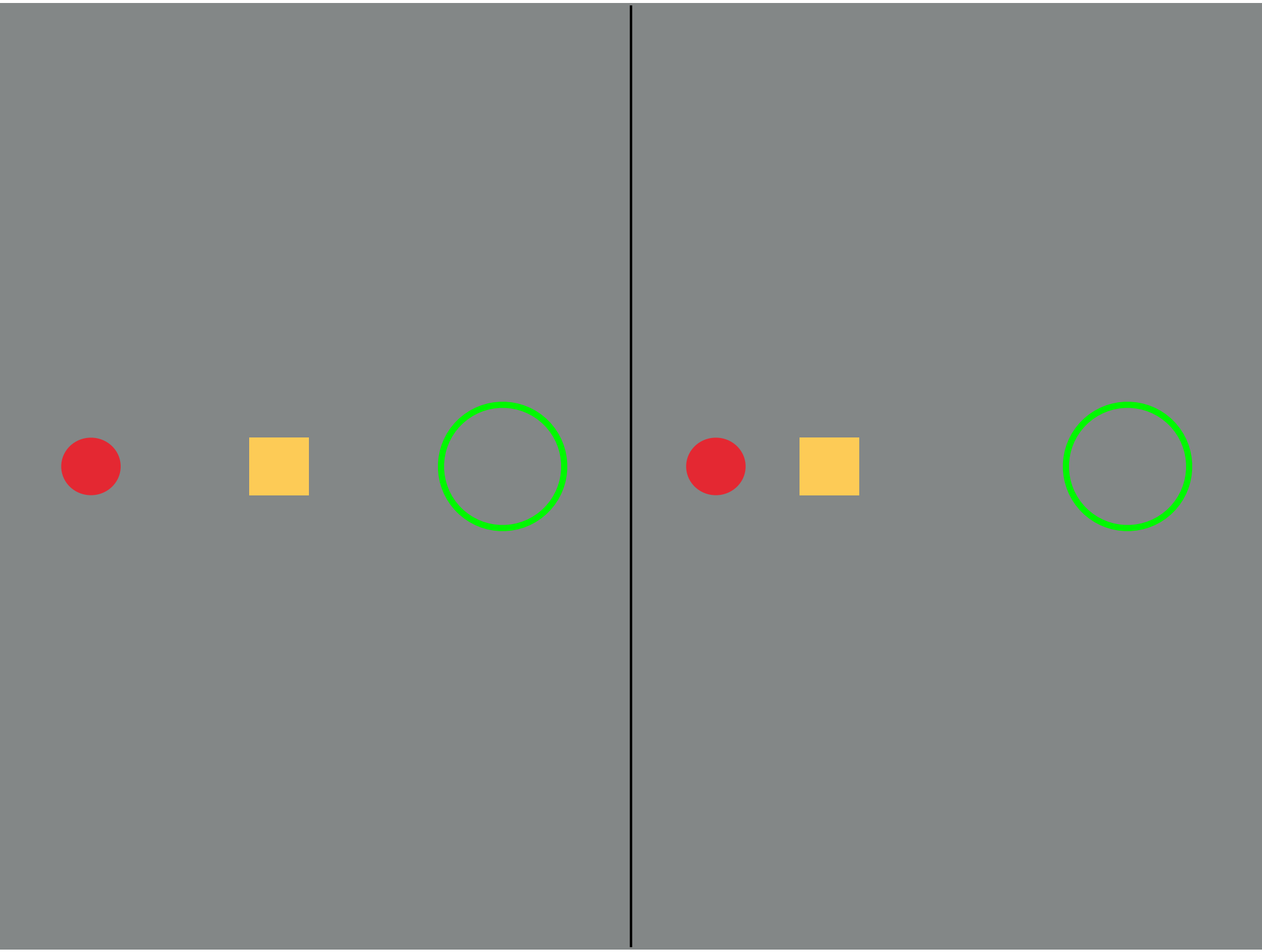
2 TRAINING SESSIONS, 100 TRIALS EACH (SPLIT INTO 2 BLOCKS OF 50), SEPARATED BY ~1 WEEK, ORDER COUNTERBALANCED BETWEEN (8) SUBJECTS

SIMULATE CENTRAL BLIND-SPOT...

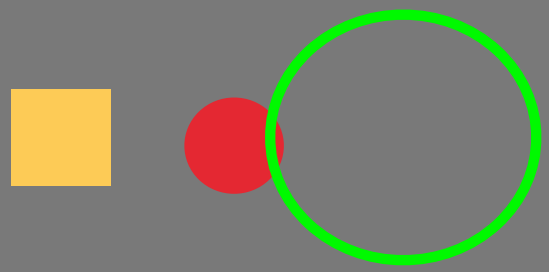

"IF YOU GET TOO CLOSE TO PUTTING YOUR CENTER OF VISION OVER THE TARGET. . ."
". . .IT'LL BE REMOVED FROM THE DISPLAY."

SIMULATE ORIENTATION/ DISTANCE/"HABITUAL PLACEMENT" CHANGE...



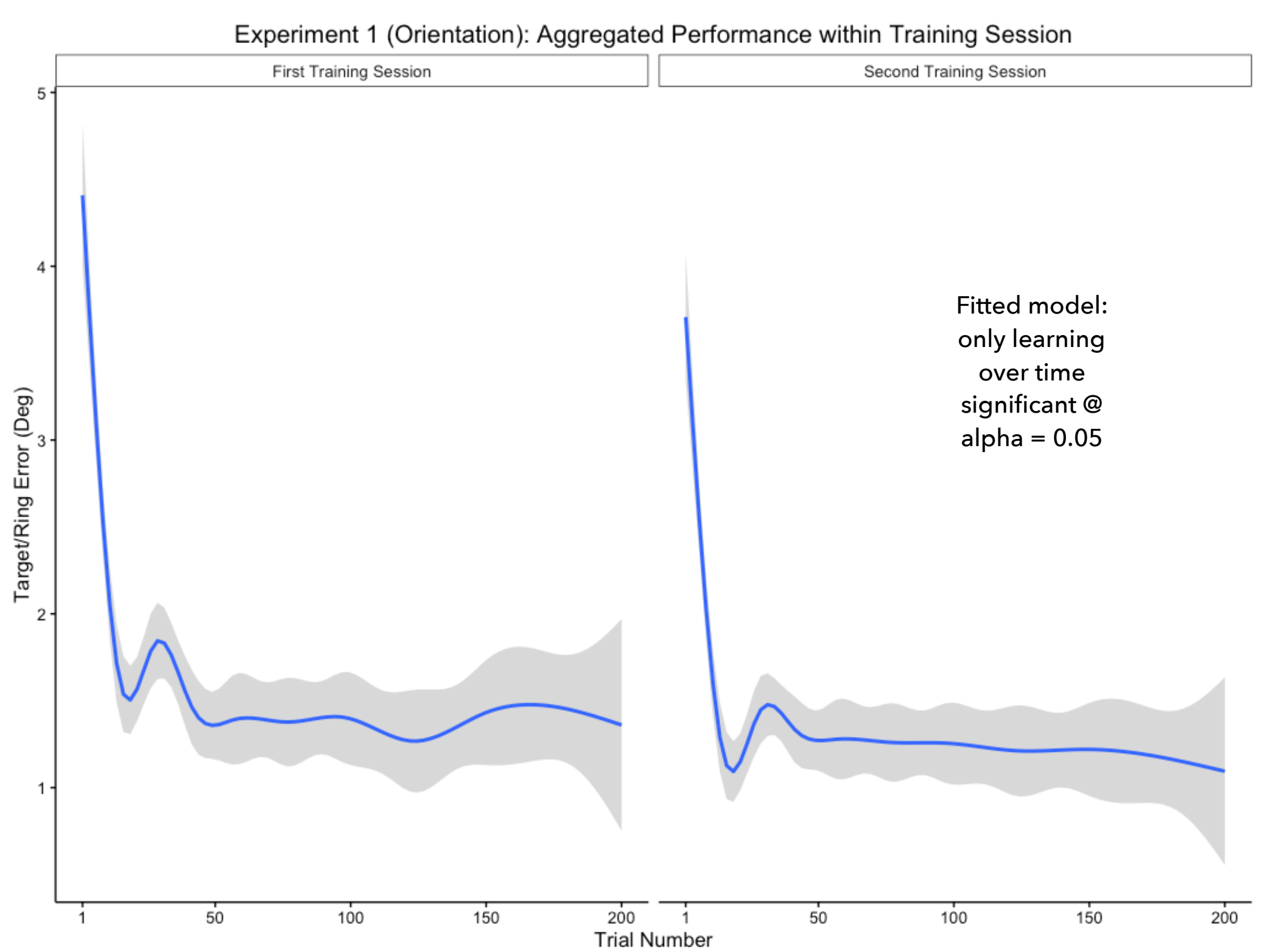


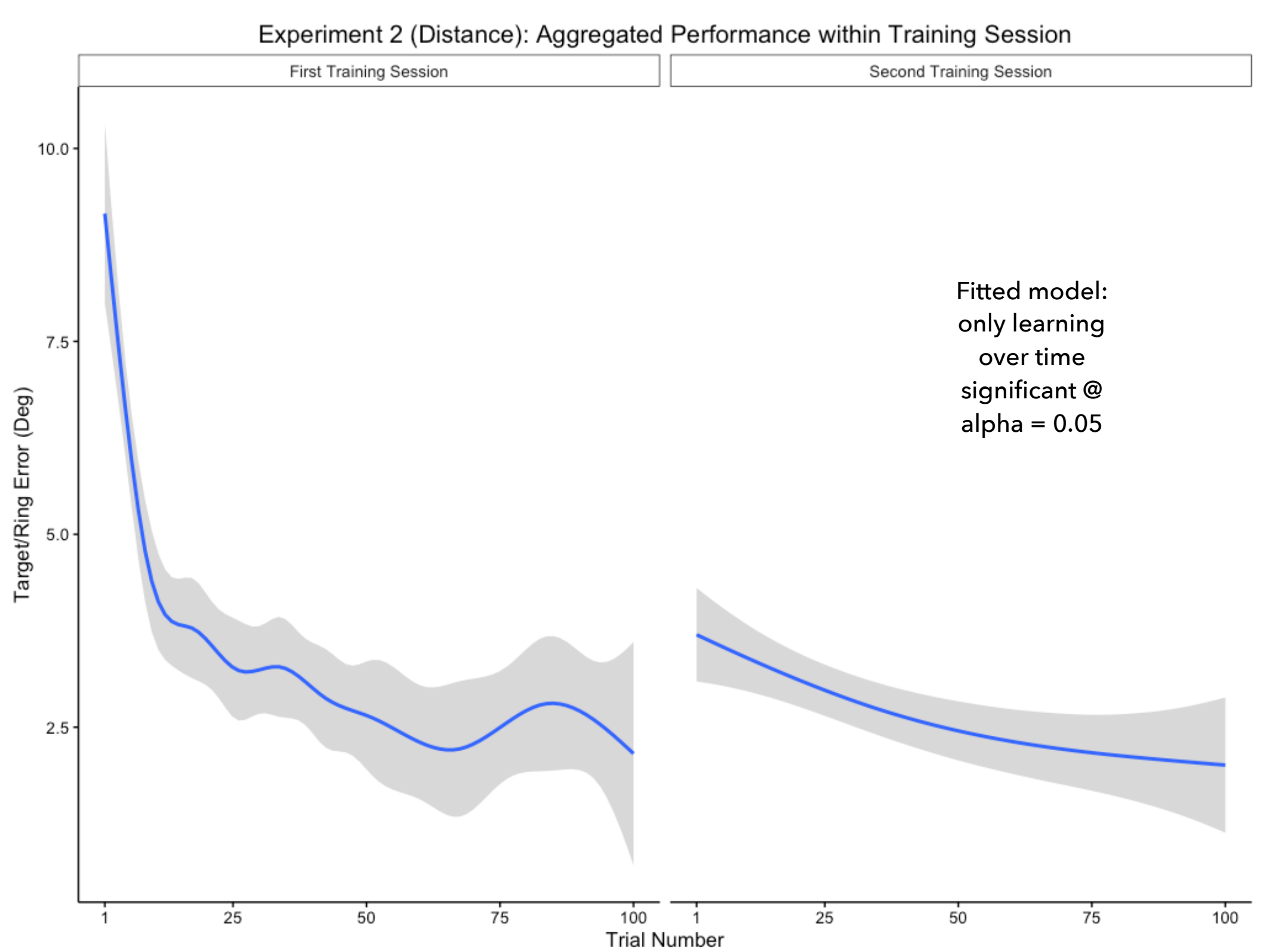
PROVIDE PERFORMANCE FEEDBACK...



RESULTS

QUESTION 1: DOES TRAINING IMPROVE PERIPHERAL FIXATION STABILITY?

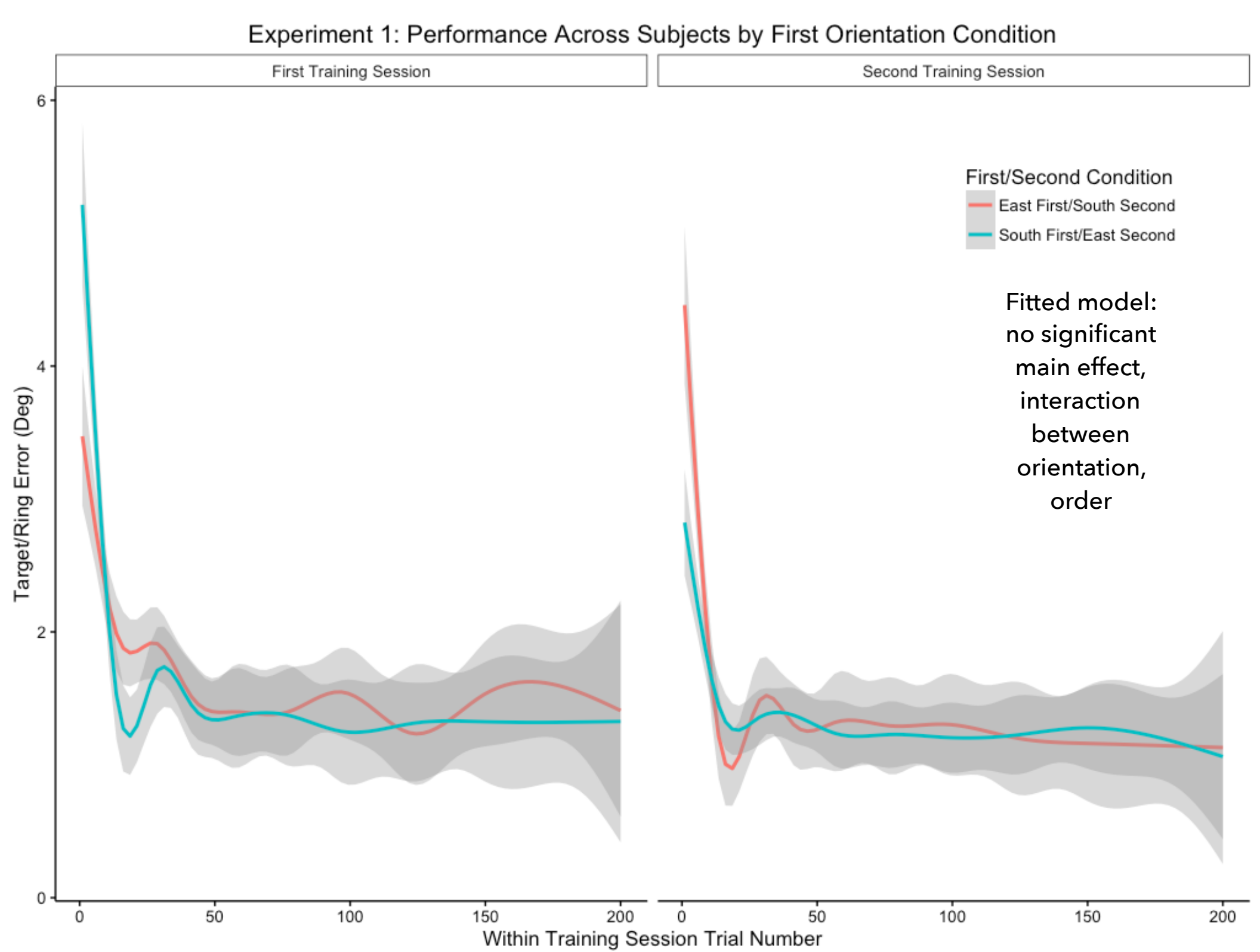

Experiment 1 (Orientation): Aggregated Performance within Training Session
First Training Session
Second Training Session
Target/Ring Error (Deg)
5
4
3
2
1
1
50
100
150
200
Trial Number
Fitted model:
only learning
over time
significant @
alpha = 0.05

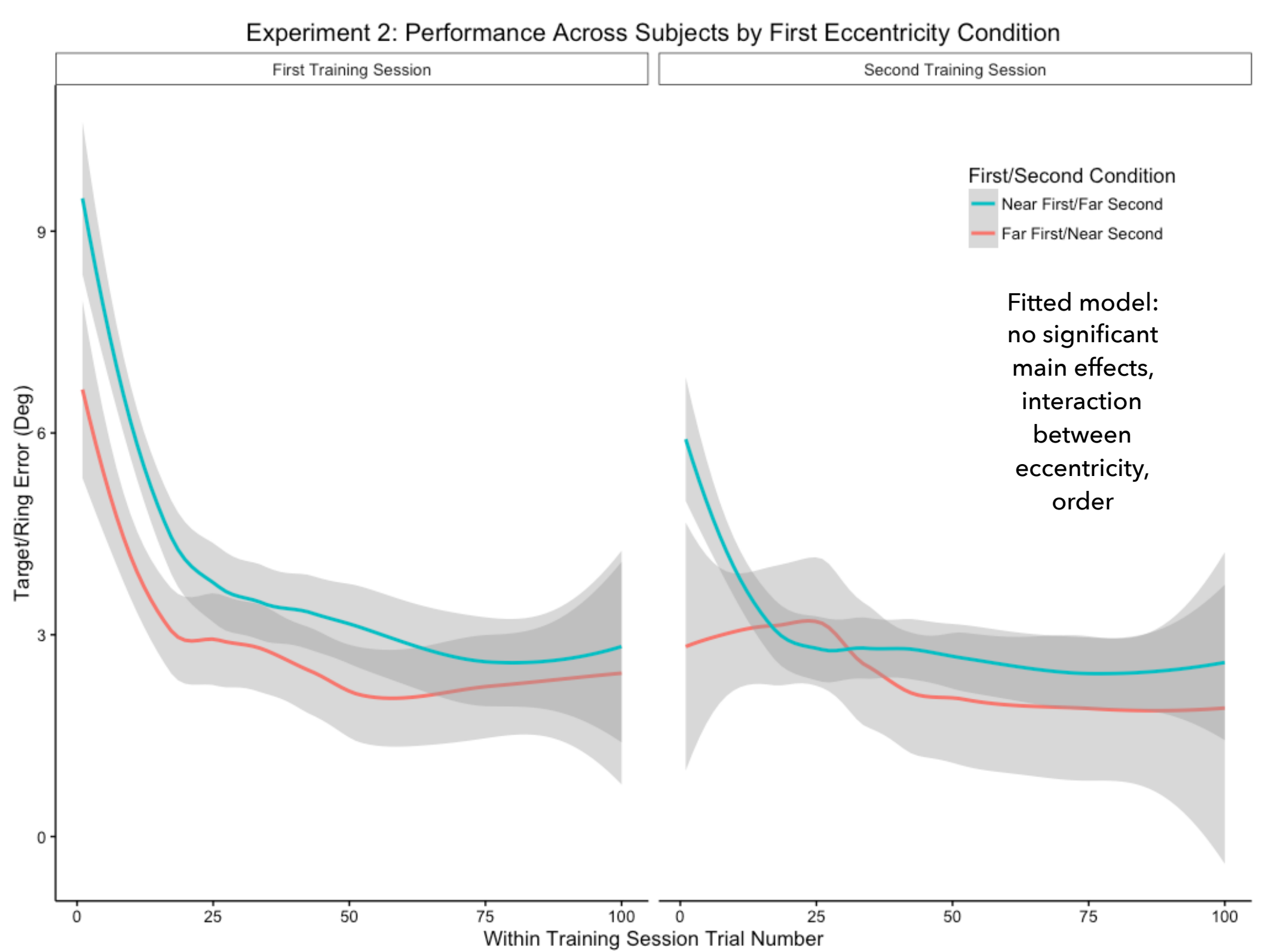

Experiment 2 (Distance): Aggregated Performance within Training Session
First Training Session
Second Training Session
Target/Ring Error (Deg)
10.0
7.5
5.0
2.5
1
25
50
75
100
Trial Number
Fitted model:
only learning
over time
significant @
alpha = 0.05

QUESTION 1: DOES TRAINING IMPROVE PERIPHERAL FIXATION STABILITY?

YES

QUESTIONS 2: DO ORIENTATION/ ECCENTRICITY/CONDITION ORDER AFFECT PERFORMANCE?

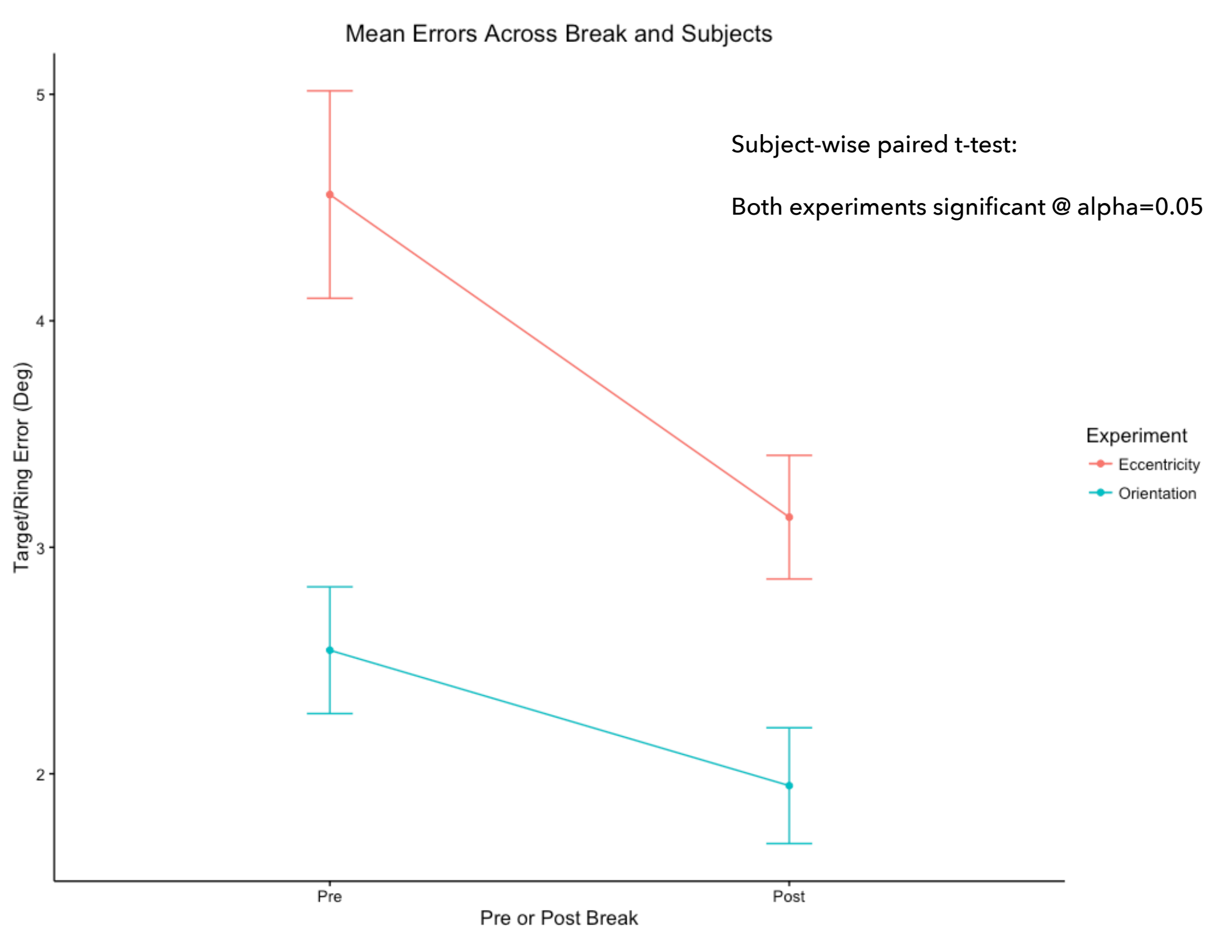

Experiment 1: Performance Across Subjects by First Orientation Condition
First Training Session
Second Training Session
First/Second Condition
East First/South Second
South First/East Second
Fitted model: no significant main effect, interaction between orientation, order
Target/Ring Error (Deg)
0
2
4
6
0
50
100
150
200
Within Training Session Trial Number


Experiment 2: Performance Across Subjects by First Eccentricity Condition
First Training Session
Second Training Session
First/Second Condition
Near First/Far Second
Far First/Near Second
Fitted model: no significant main effects, interaction between eccentricity, order
Target/Ring Error (Deg)
0
3
6
9
0
25
50
75
100
Within Training Session Trial Number

QUESTION 2: DO ORIENTATION/ ECCENTRICITY/CONDITION ORDER AFFECT PERFORMANCE?

NO (BUT WE NEED TO DIG INTO "FAR" CONDITION FURTHER)

QUESTIONS 3: DO EFFECTS OF TRAINING PERSIST BETWEEN SESSIONS? SURVIVE CHANGES IN ORIENTATION/ECCENTRICITY?


Mean Errors Across Break and Subjects
Target/Ring Error (Deg)
5
4
3
2
Pre
Post
Pre or Post Break
Experiment
Eccentricity
Orientation
Subject-wise paired t-test:
Both experiments significant @ alpha=0.05

QUESTIONS 3: DO EFFECTS OF TRAINING PERSIST BETWEEN SESSIONS? SURVIVE CHANGES IN ORIENTATION/ECCENTRICITY?

YES

DISCUSSION

WHAT HAVE WE SHOWN?

- Can significantly improve fixational stability in visual periphery
- Improvements not dependent on orientation/eccentricity of site of training
- Improvements survive extinction between training periods and changes in orientation/eccentricity

WHAT HAVEN'T WE SHOWN?

- *Feedback* specific effect vs. general task-learning over time
- Absolute magnitude of gains relative to healthy control performance @ fovea
- *Functional* benefits as function of fixational stabilization
- All planned follow-ups/controls!

OK, BUT WHY DOES ANY OF THIS REALLY MATTER?

IT MATTERS BECAUSE:

- Effectively models/simulates real process of adaptation to peripheral fixation in disease populations
- Good simulation: easier to use for study than patients!
- Moreover:
  - Demonstrate equivalence to process in patients, show independent effect of *feedback* over time: possibility for rehabilitation technique? Other, non-clinical applications? ;)


Yoroshikuma!
(Thank-you-beary-much!)