Using the peripheral visual field for spatial orientation

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Three primary sources of spatial orientation

1. Vision relates the orientation of the body to an externally fixed frame of reference. When visibility is good, vision dominates spatial orientation.
2. The equilibrium sense (the otoliths) assumes that the g-force is vertical. Often incorrect in the flight situation.
3. Proprioception relies on the g-force as well.

- When visibility is bad, the otoliths and proprioception takes over spatial orientation which give rise to numerous illusions causing fatal misjudgements in the flight situation

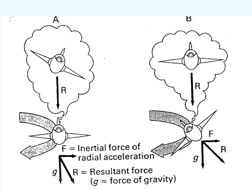


Figure 21.1 False perception of attitude—the somatogravic illusion—in a turn. The pilot equates the sustained resultant (R) with the vertical. Hence in a flat turn (A) he may feel as if rolled out of the turn. In the more usual co-ordinated turn (B) the resultant is aligned with his Z axis and he has no sensation of being banked in attitude.

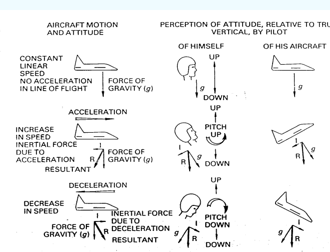


Figure 21.2 Somatogravic illusions during linear acceleration in the line of flight give error in the perception of pitch attitude.

These illusions are overcome if structured visual information is provided.

It is the ambient visual field that mediates information for spatial orientation. No special priority for the fovea.

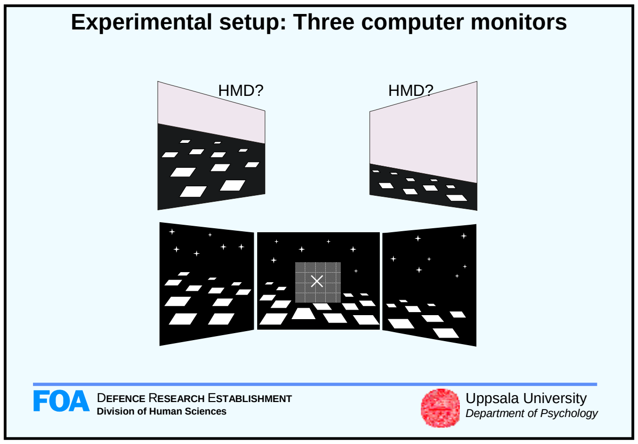
a) Gunnar Johansson’s experiments
b) Lee’s visual kinesthesis

How should visual information be presented?

- The HDD are too cognitive. Does not resonate with the perceptual system
- The Malcolm horizon (wide field artificial horizon).
- Wide field artificial surrounding anchored to the external world. To be effective it has to fully compensate for the motion of the aircraft and the movements of the subject.

Experimental questions

1. How important is visual flow?
2. What kind of ground patterning should be used?
3. How much of the central visual field can be left out for other focal visual tasks?
4. How should the artificial visual field be presented? HMD or displayed on the sides of the cockpit?


Experimental setup: Three computer monitors
HMD?
HMD?
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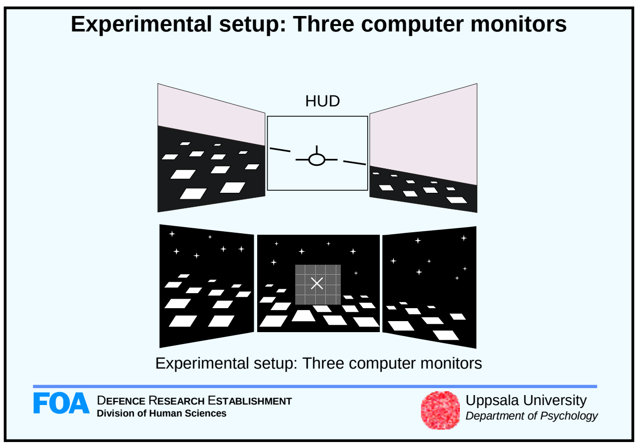
Experimental setup: Three computer monitors
HUD
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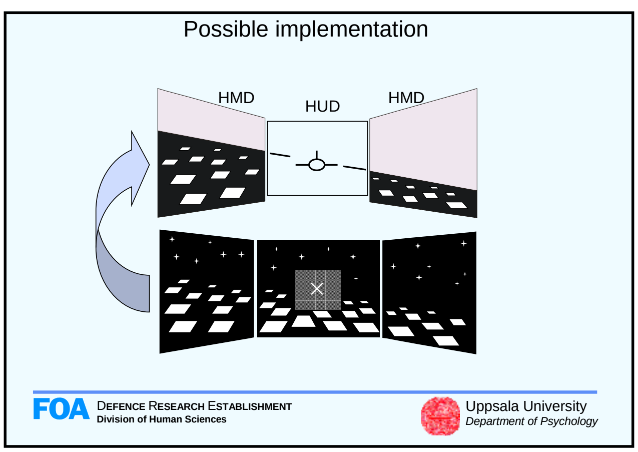
Possible implementation
HMD
HUD
HMD
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Experiments I & II
GENERAL

Principle: Instead of studying how an externally anchored visual display stabilizes spatial orientation in an environment with varying g-force, we study how an independently changing visual display deteriorates spatial orientation in an environment with stable g-force (easier to implement).

The idea is that in each of these situations we can measure the importance of the visual determinants relative to the ones based on the g-force (proprioception and equilibrium sense).

Instead of measuring the effect of perceived spatial orientation on manouvering an aircraft, we mesure its effect on balance.

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Experiments I & II

The visual display

- Horizon with textured ground beneath it in the virtual world:

  White rectangles distributed on a black ground with increasing texture element density towards a clearly defined horizon, and a starry sky.

- When in motion generating “optic flow”:

  Slow forward motion: 3 rectangle elements / s ≈ 1º / 0.2 s

  Fast forward motion: 12 rectangle elements / s ≈ 1º / 0.05 s

- Roll sequences of horizon: slow and fast 15º roll motion

  Slow = 15º in 3.3 s, 2.5 s in pos., 3.3 s back to horizontal

  Fast = 15º in 0.6 s, 2.5 s in pos., 0.6 s back to horizontal

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Experiments I & II

- Each of 3 displays 45º horizontally and 34º vertically
  and gaps between displays of 7.5º x 2 **= 150º x 34º**

The procedure

- Participants in the “Sharpened Romberg Stance”

  Erect stance with one foot in front of the other (heel to toe)

  16 participants in experiments I & II, respectively

Recording of movements

- Head-tracker system registers translational and rotational X, Y, Z changes of head position at 30 Hz

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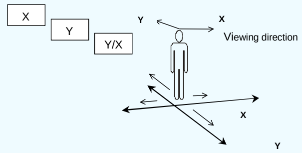
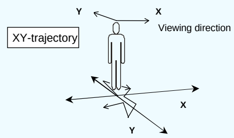
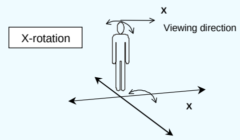
Measures



- Mean change for each measure, computed from registered changes in each roll motion sequence
- From start of roll to back to horizontal





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EXPERIMENT I

- One full-view display configuration: 150º x 34º
- Four conditions: Central field with no presentation (fix. cross)
  Sizes: 10º x 10º
  20º x 20º
  30º x 30º
  40º x 34º
- Each of the five display configurations presented in separate trials
- Each trial begins and ends with NO FORWARD MOTION but with roll motion sequences.
  In between, SLOW and FAST FORWARD MOTIONS combined with roll motion sequences.

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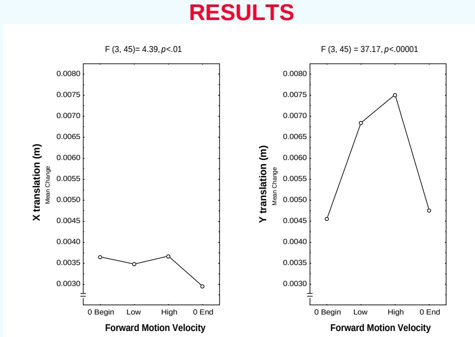
RESULTS



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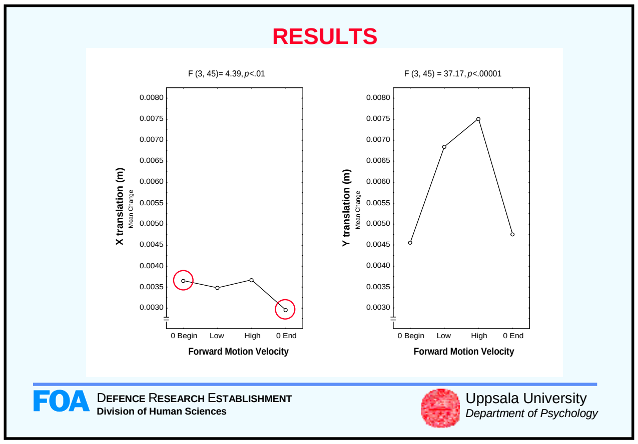
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F (3, 45) = 37.17, p<.00001
X translation (m)
Mean Change
Y translation (m)
Mean Change
0.0080
0.0075
0.0070
0.0065
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
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0 Begin
Low
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Forward Motion Velocity
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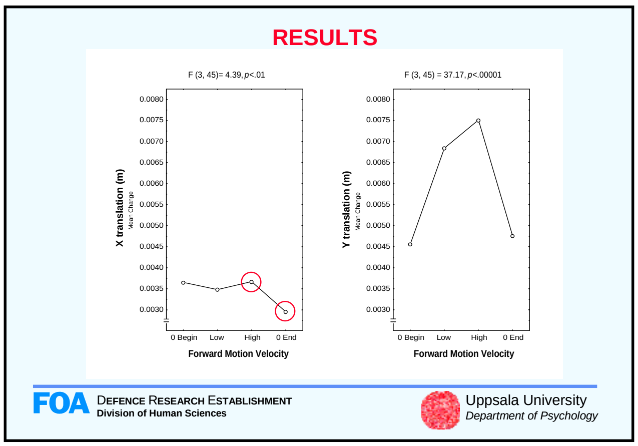
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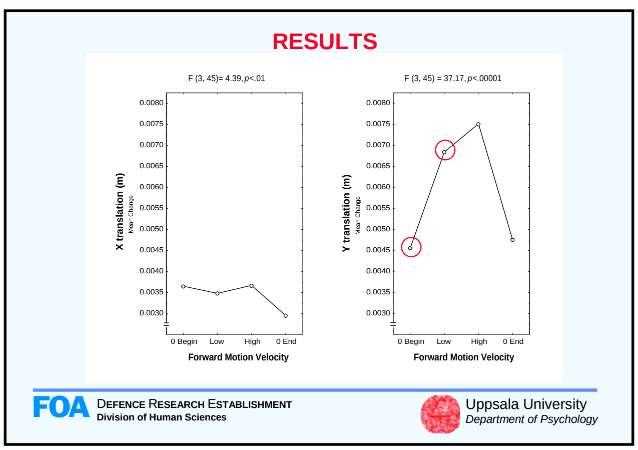
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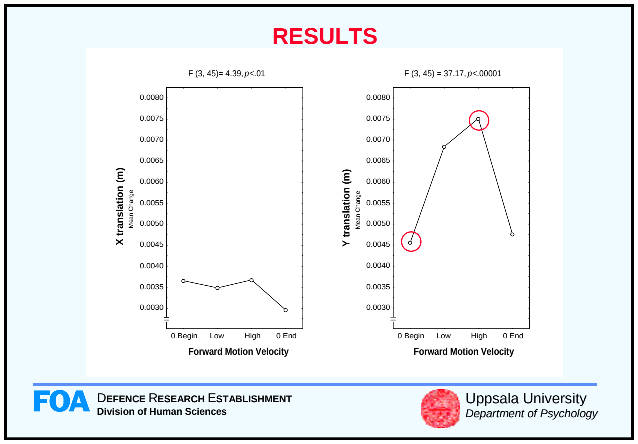
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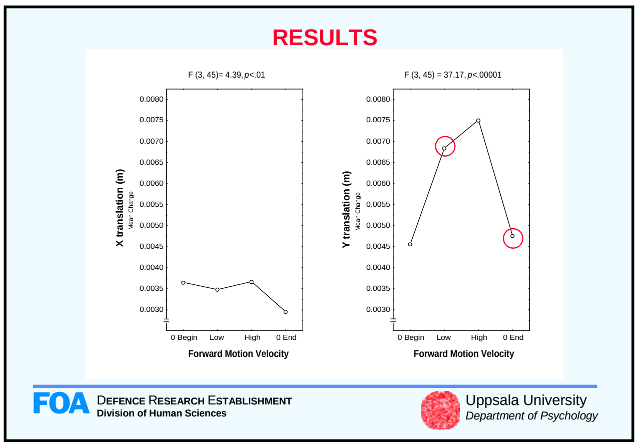
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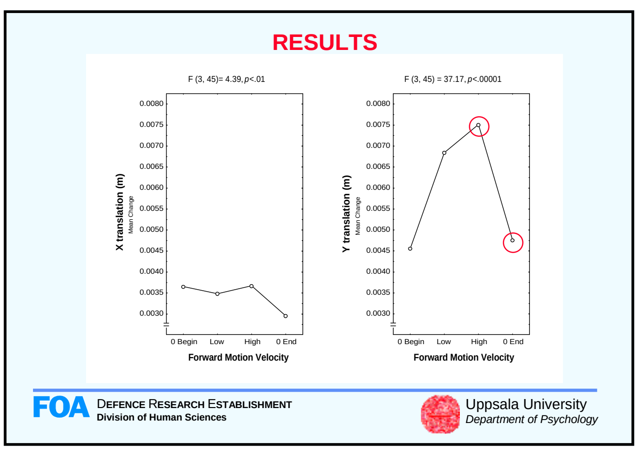
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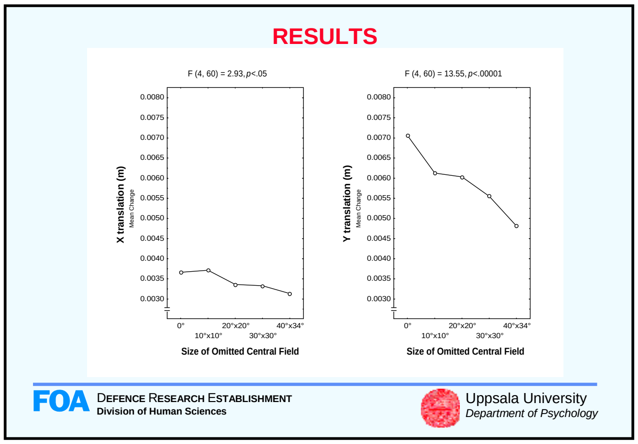
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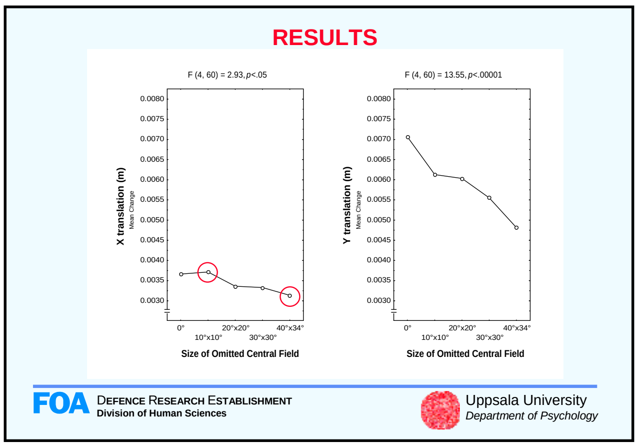
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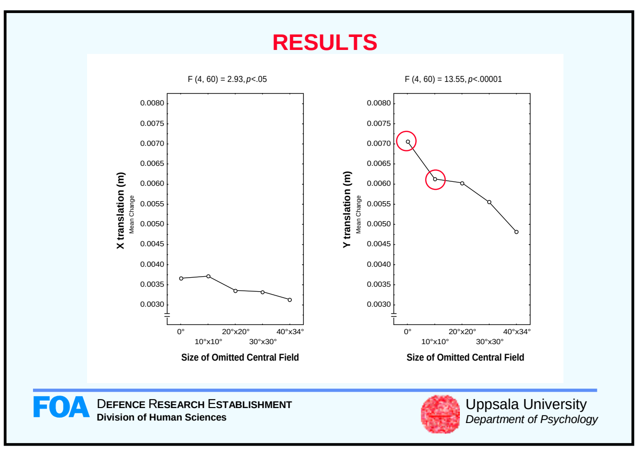
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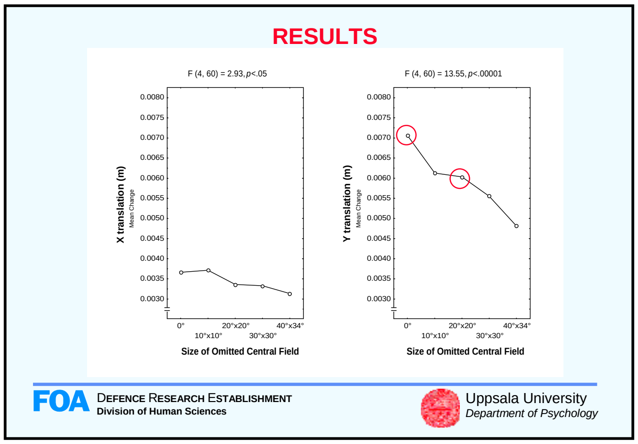
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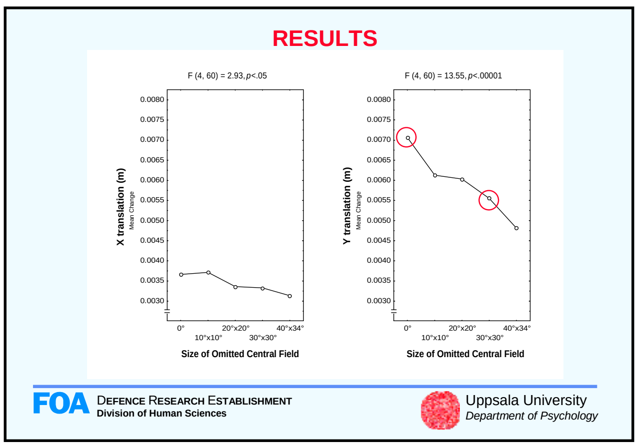
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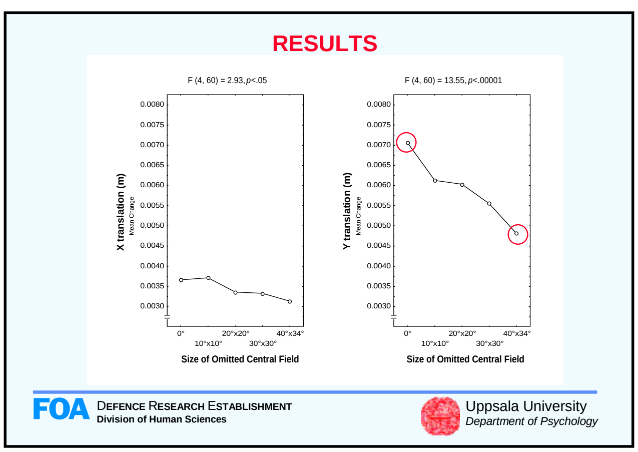
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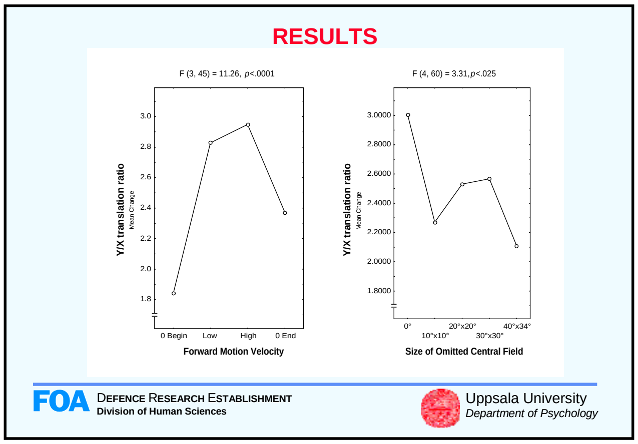
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F (4, 60) = 3.31, p<.025
Y/X translation ratio
Mean Change
3.0
2.8
2.6
2.4
2.2
2.0
1.8
0 Begin
Low
High
0 End
Forward Motion Velocity
3.0000
2.8000
2.6000
2.4000
2.2000
2.0000
1.8000
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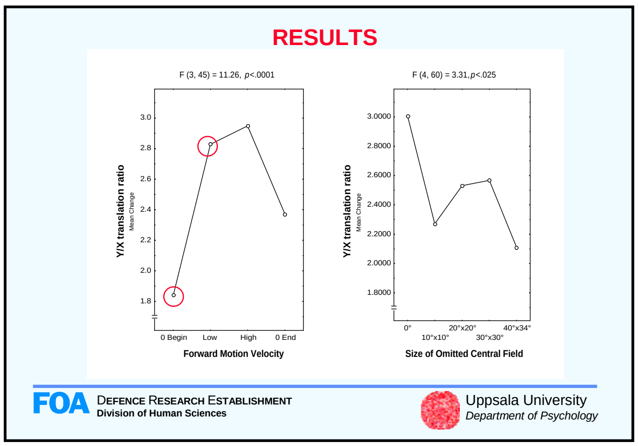
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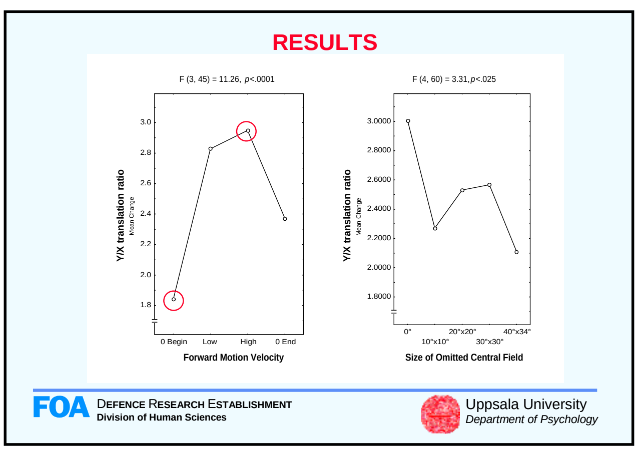
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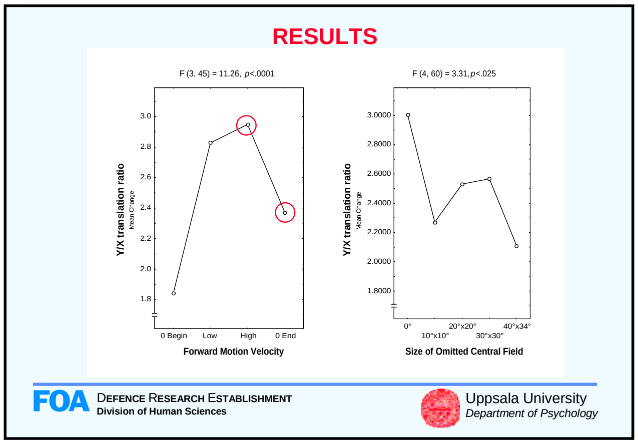
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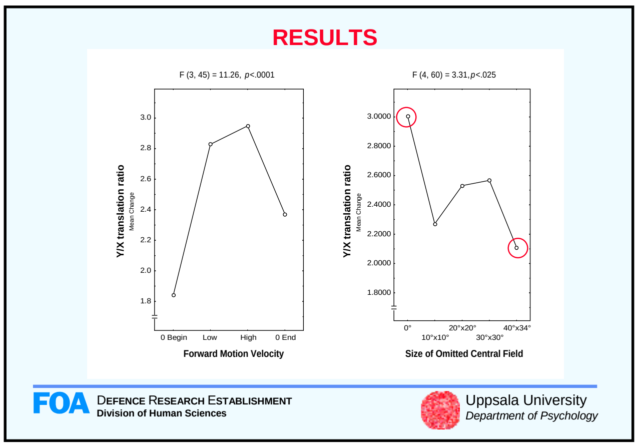
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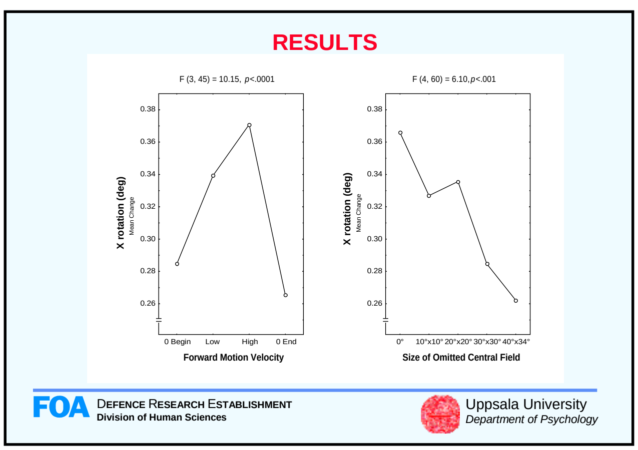
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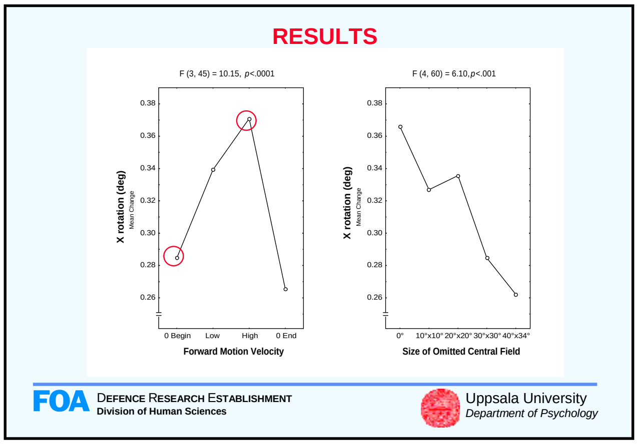
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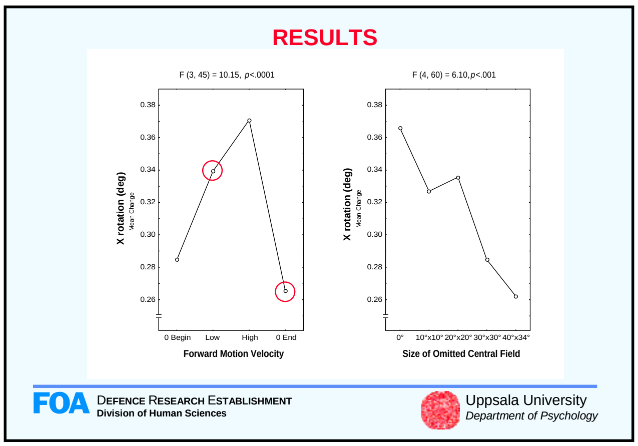
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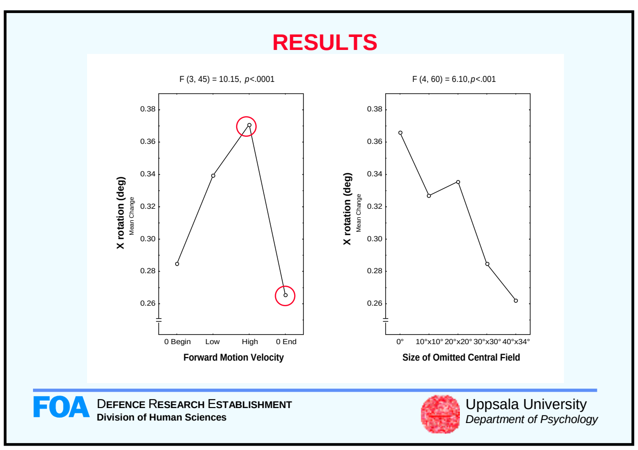
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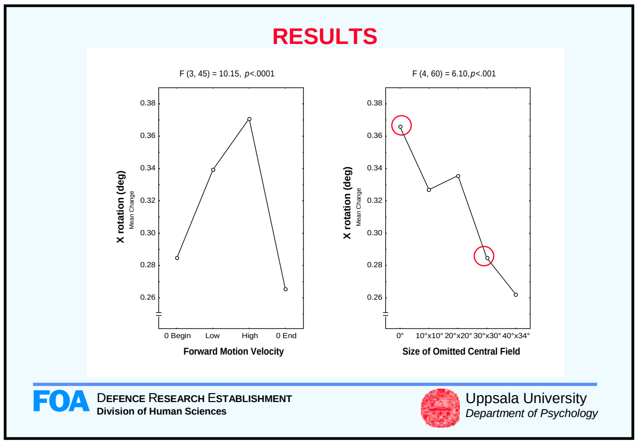
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F (3, 45) = 10.15, p<.0001
F (4, 60) = 6.10, p<.001
X rotation (deg)
Forward Motion Velocity
0 Begin
Low
High
0 End
Size of Omitted Central Field
FOA
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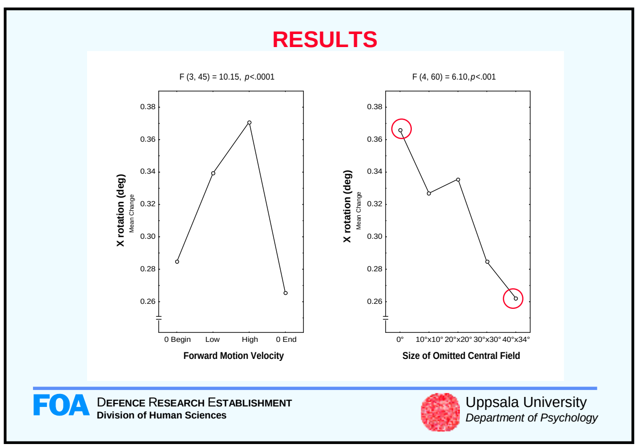
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X rotation (deg)
Forward Motion Velocity
0 Begin
Low
High
0 End
Size of Omitted Central Field
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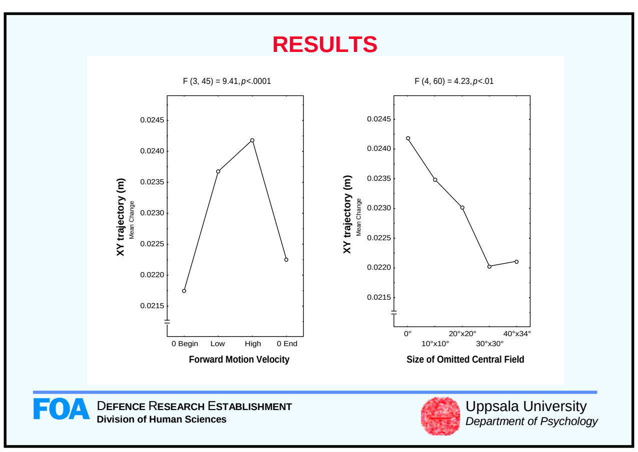
RESULTS
F (3, 45) = 9.41, p<.0001
F (4, 60) = 4.23, p<.01
XY trajectory (m)
Forward Motion Velocity
0 Begin
Low
High
0 End
Size of Omitted Central Field
FOA
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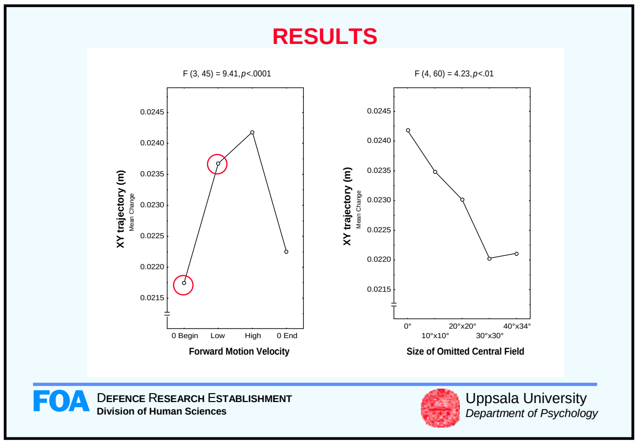
RESULTS
F (3, 45) = 9.41, p<.0001
F (4, 60) = 4.23, p<.01
XY trajectory (m)
Mean Change
0 Begin
Low
High
0 End
Forward Motion Velocity
0°
10°x10°
20°x20°
30°x30°
40°x34°
Size of Omitted Central Field
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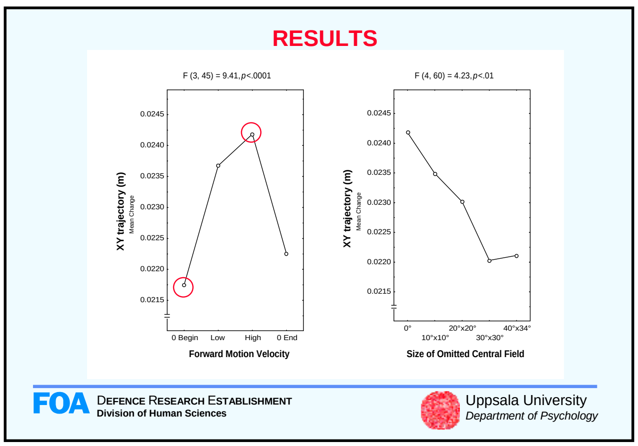
RESULTS
F (3, 45) = 9.41, p<.0001
F (4, 60) = 4.23, p<.01
XY trajectory (m)
Mean Change
0 Begin
Low
High
0 End
Forward Motion Velocity
0°
10°x10°
20°x20°
30°x30°
40°x34°
Size of Omitted Central Field
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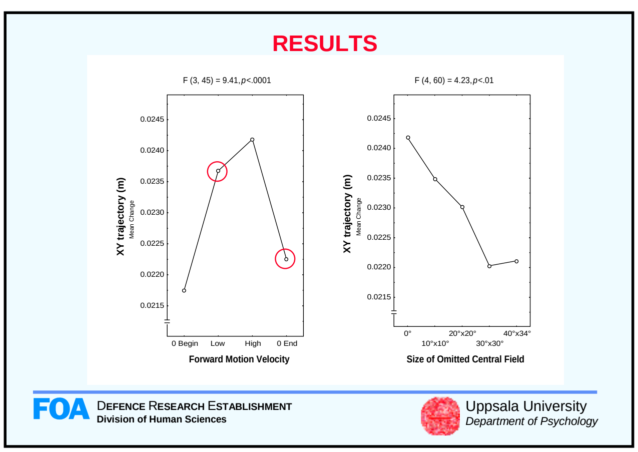
RESULTS
F (3, 45) = 9.41, p<.0001
F (4, 60) = 4.23, p<.01
XY trajectory (m)
Mean Change
0 Begin
Low
High
0 End
Forward Motion Velocity
0°
10°x10°
20°x20°
30°x30°
40°x34°
Size of Omitted Central Field
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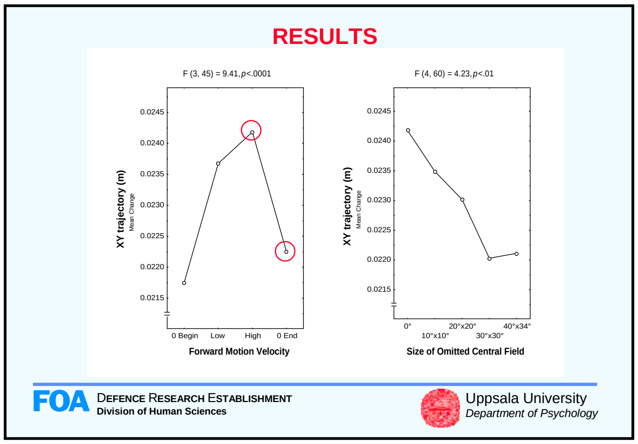
RESULTS
F (3, 45) = 9.41, p<.0001
F (4, 60) = 4.23, p<.01
XY trajectory (m)
Mean Change
0.0245
0.0240
0.0235
0.0230
0.0225
0.0220
0.0215
0 Begin
Low
High
0 End
Forward Motion Velocity
0°
10°x10°
20°x20°
30°x30°
40°x34°
Size of Omitted Central Field
FOA
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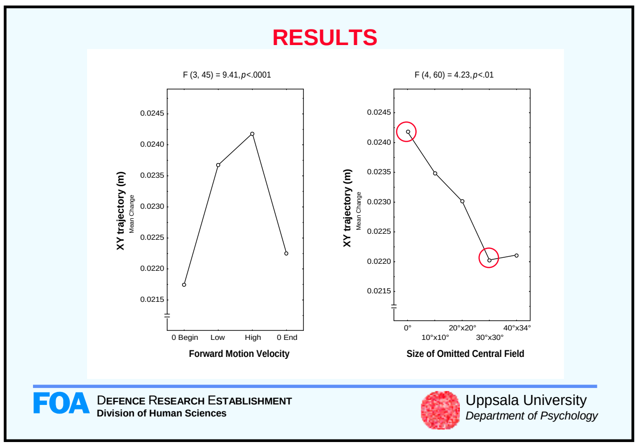
RESULTS
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F (4, 60) = 4.23, p<.01
XY trajectory (m)
Mean Change
0.0245
0.0240
0.0235
0.0230
0.0225
0.0220
0.0215
0 Begin
Low
High
0 End
Forward Motion Velocity
0°
10°x10°
20°x20°
30°x30°
40°x34°
Size of Omitted Central Field
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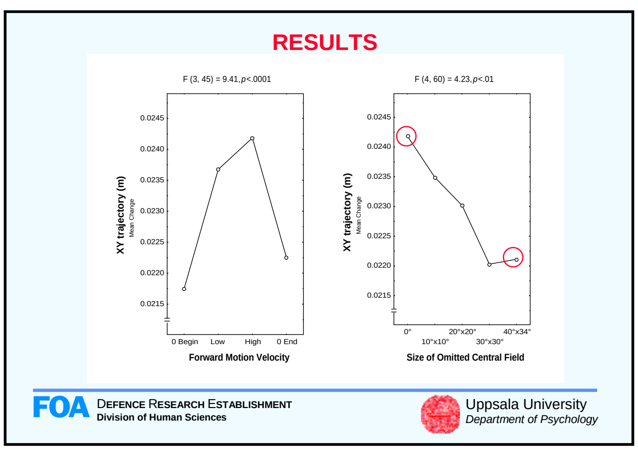
RESULTS
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F (4, 60) = 4.23, p<.01
XY trajectory (m)
Mean Change
0.0245
0.0240
0.0235
0.0230
0.0225
0.0220
0.0215
0 Begin
Low
High
0 End
Forward Motion Velocity
0°
10°x10°
20°x20°
30°x30°
40°x34°
Size of Omitted Central Field
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CONCLUSIONS
Experiment I

Overall,

- Greater postural instability with SLOW and FAST forward motions as compared with the conditions with zero forward velocity

- Up to 20º x 20º of the central visual field can be omitted with postural instability as effectively caused as with a full-view display

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EXPERIMENT II

- Nine displays: Central field / Horizontal field

0º / 150º	0º / 105º	0º / 45º
20ºx20º / 150º	20ºx20º / 105º	20ºx20º / 45º
30ºx30º / 150º	30ºx30º / 105º	30ºx30º / 45º

- Each of the nine display configurations presented in separate trials
- Every trial: SLOW and FAST FORWARD motions combined with roll motion sequences

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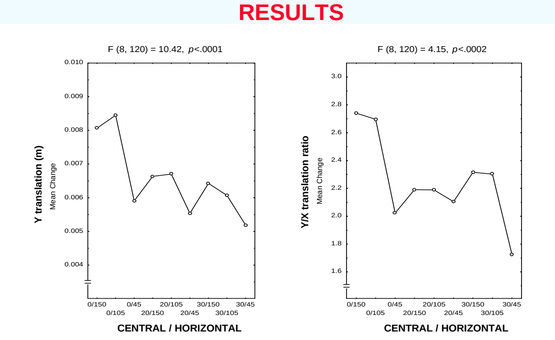
RESULTS



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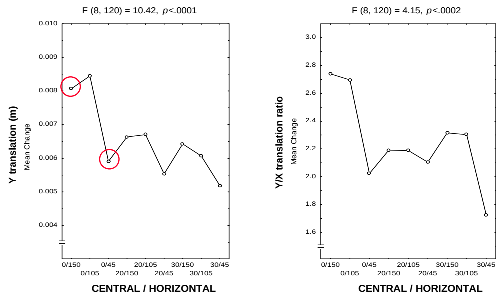
RESULTS



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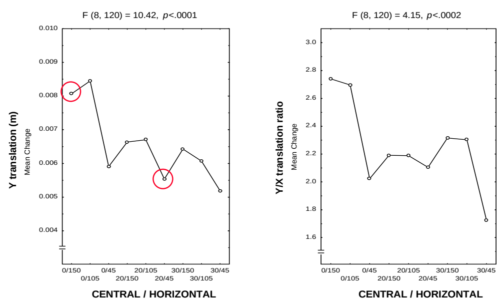
RESULTS



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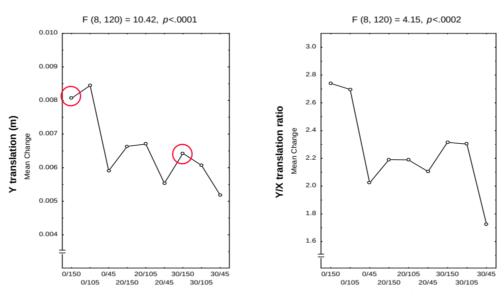
RESULTS



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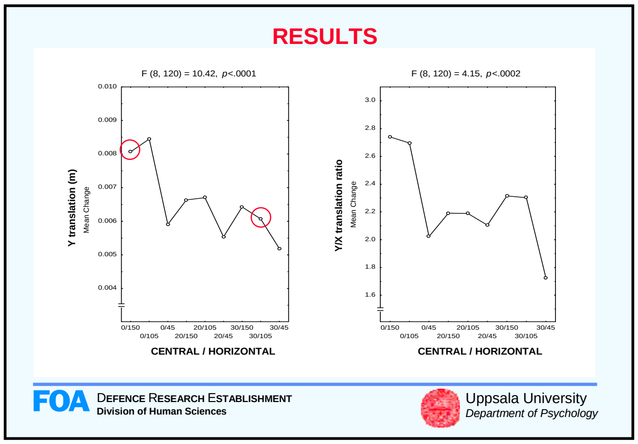
RESULTS
F (8, 120) = 10.42, p<.0001
Y translation (m)
Mean Change
CENTRAL / HORIZONTAL
F (8, 120) = 4.15, p<.0002
Y/X translation ratio
Mean Change
CENTRAL / HORIZONTAL
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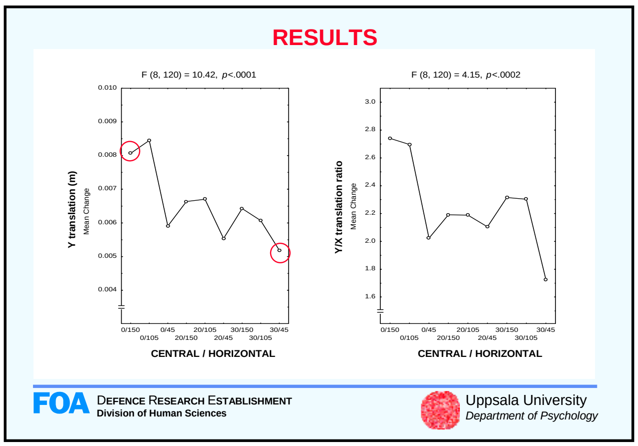
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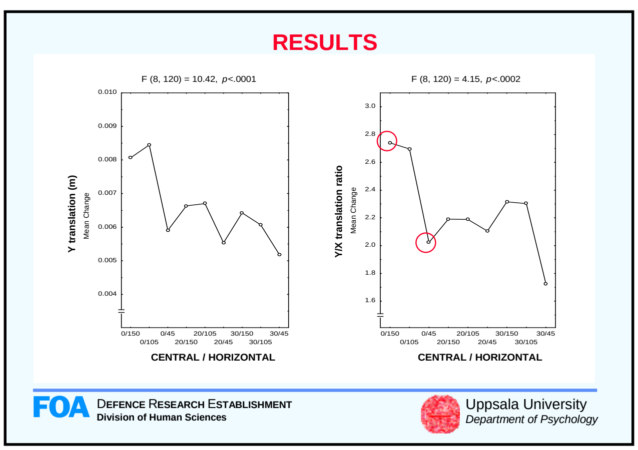
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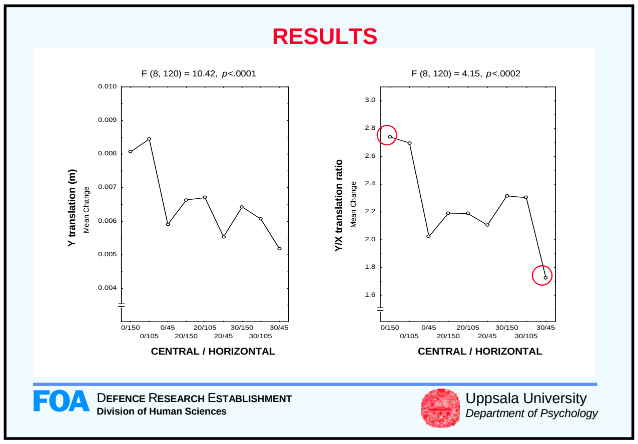
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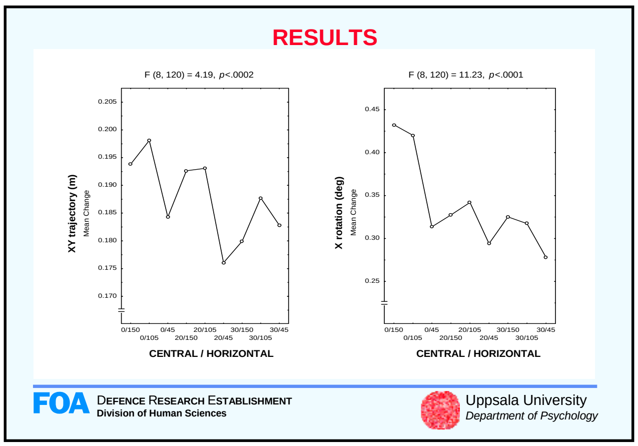
RESULTS
F (8, 120) = 4.19, p<.0002
XY trajectory (m)
Mean Change
CENTRAL / HORIZONTAL
F (8, 120) = 11.23, p<.0001
X rotation (deg)
Mean Change
CENTRAL / HORIZONTAL
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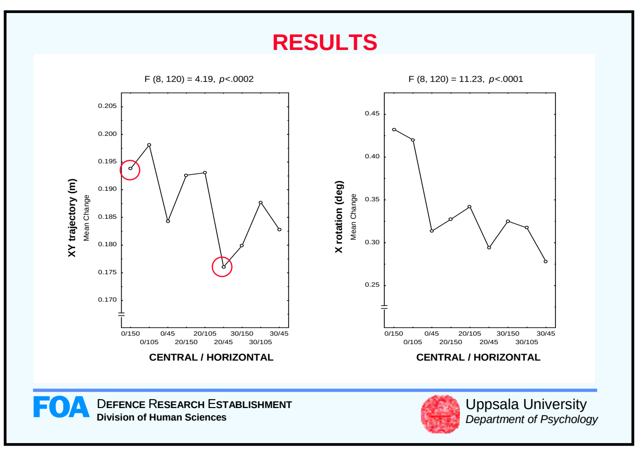
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Mean Change
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X rotation (deg)
Mean Change
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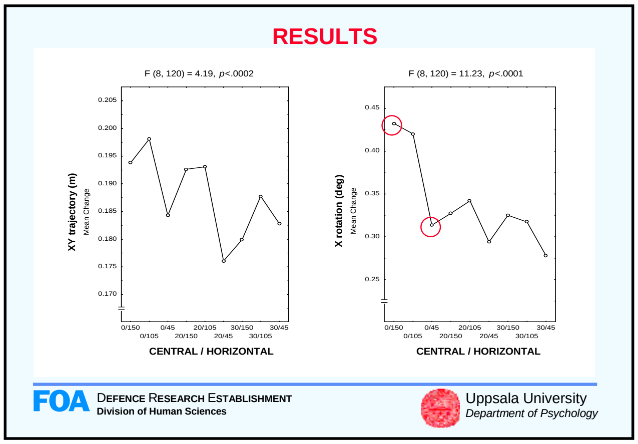
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Mean Change
X rotation (deg)
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CENTRAL / HORIZONTAL
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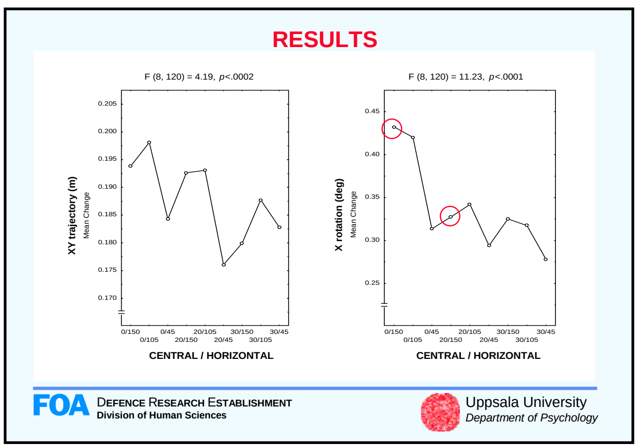
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Mean Change
X rotation (deg)
Mean Change
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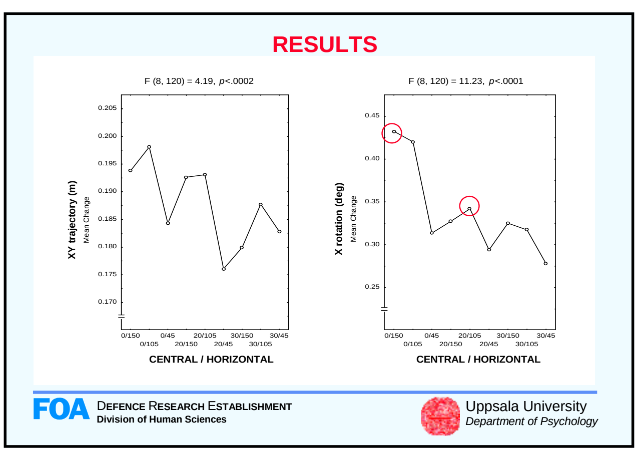
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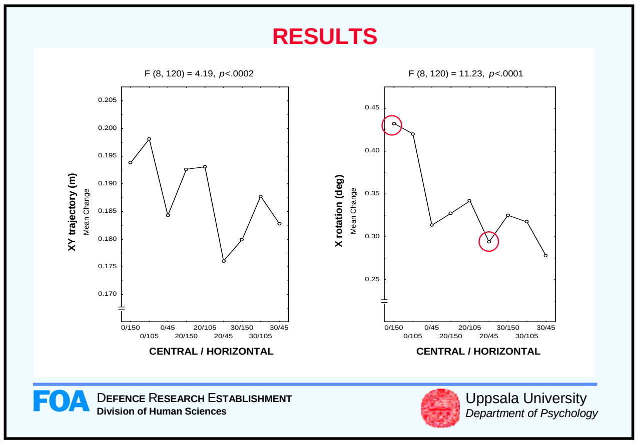
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Mean Change
X rotation (deg)
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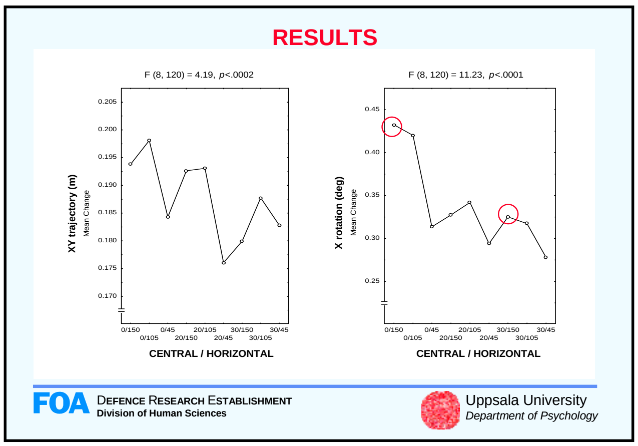
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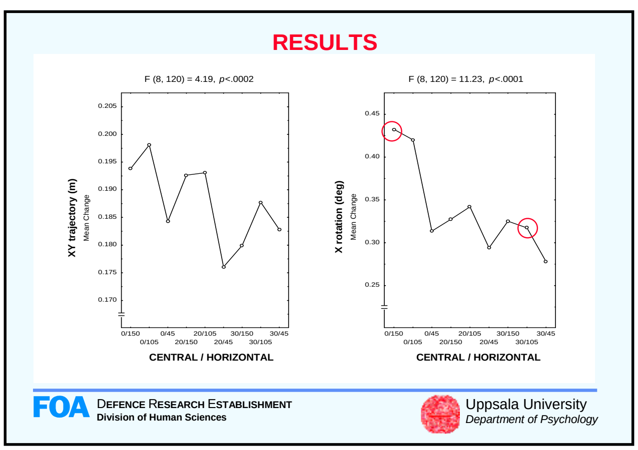
RESULTS
F (8, 120) = 4.19, p<.0002
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XY trajectory (m)
Mean Change
X rotation (deg)
Mean Change
CENTRAL / HORIZONTAL
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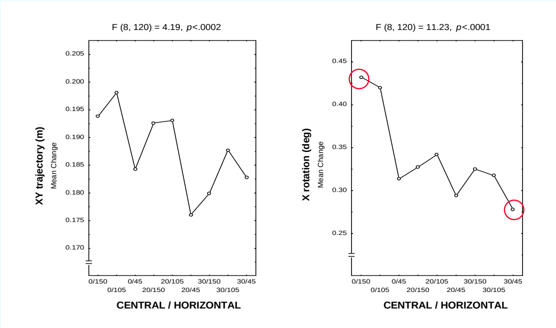
RESULTS



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CONCLUSIONS
Experiment II

Overall,

- $20^o x 20^o$ - $30^o x 30^o$ / 105^o caused postural instability as effectively as a full-view display (0^o / 150^o)

- The measure ‘X-rotation’ more sensitive to increase in omitted central field / decrease in horizontal field

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GENERAL CONCLUSIONS

- An artificial horizon with flight-adapted optic flow effectively affects postural control

-A large part of the central visual field can be left out of this display without loss of efficiency.

- This is a good visual aid candidate for counteracting or reducing spatial disorientation in the flight situation, if the display is anchored in the external world.

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Future directions

- To build and test a HMD peripheral display.
- To conduct validating experiments in an environment with varying g-force.