Implications Of Spatial Sensory Reflex Research on Primary Flight Display Design

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Outline

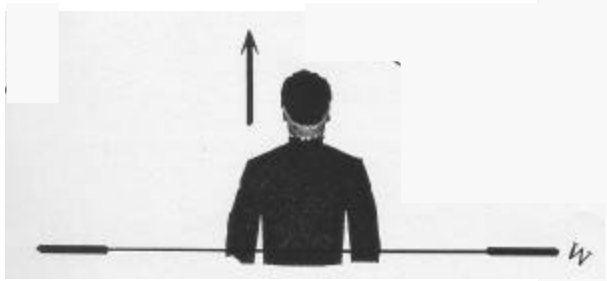
- The Problem
- Frame of Reference
- Example: How the OKCR affects display design.
- A recent study
- Research Issues for HMD Symbology
- Conclusions

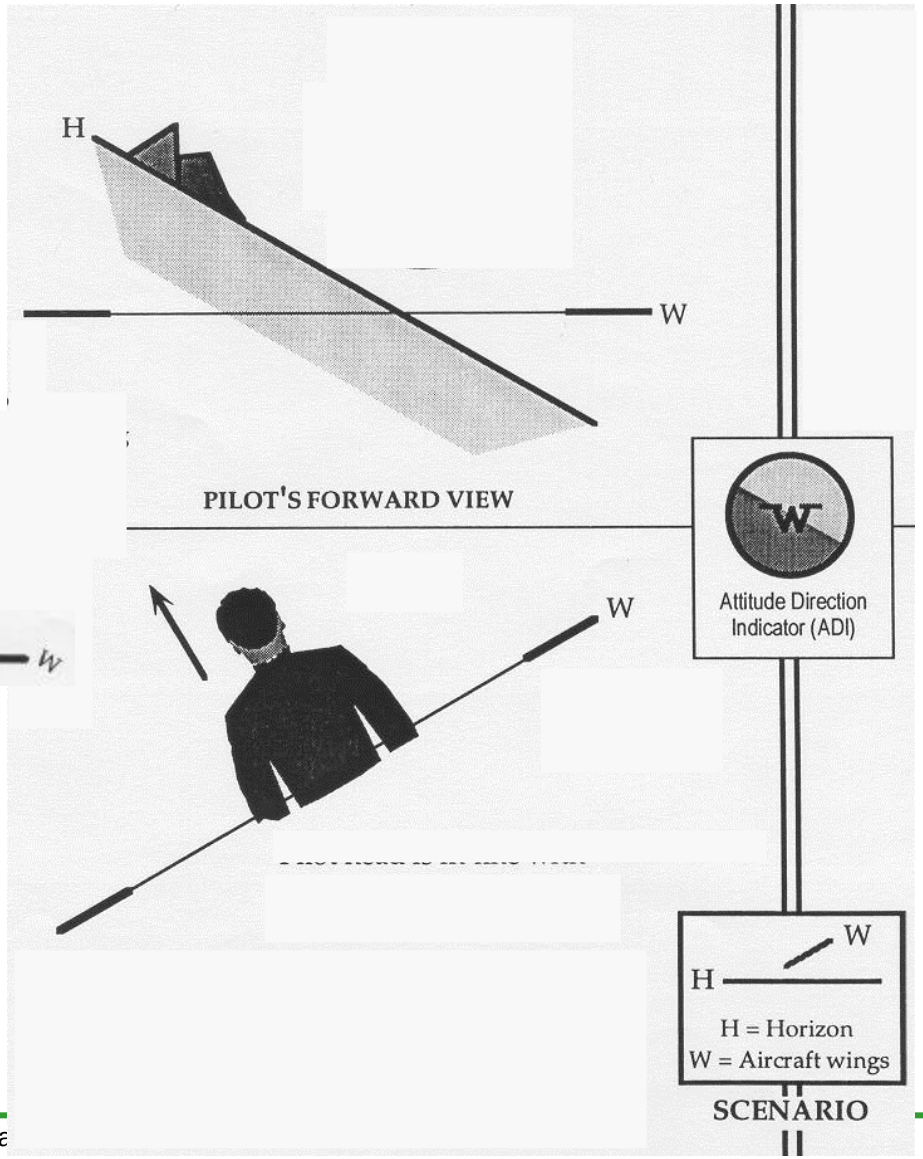
The Problem

- What frames of reference are important for a pilot to maintain orientation?
  - World - world is fixed and everything moves within it.
  - Aircraft - aircraft is fixed and everything moves around it.
  - Pilot - pilot is fixed and everything moves in relation to him.
- What symbology is appropriate for HMDs?
  - HUD symbology is being considered for use on HMDs.
  - HUD symbology is being used on NVGs.
- How do sensory reflexes affect perceived frame of reference?
  - OKCR, under VMC pilots align their head with the horizon.

Traditional Theory

Pilot's head remains aligned with the cockpit.



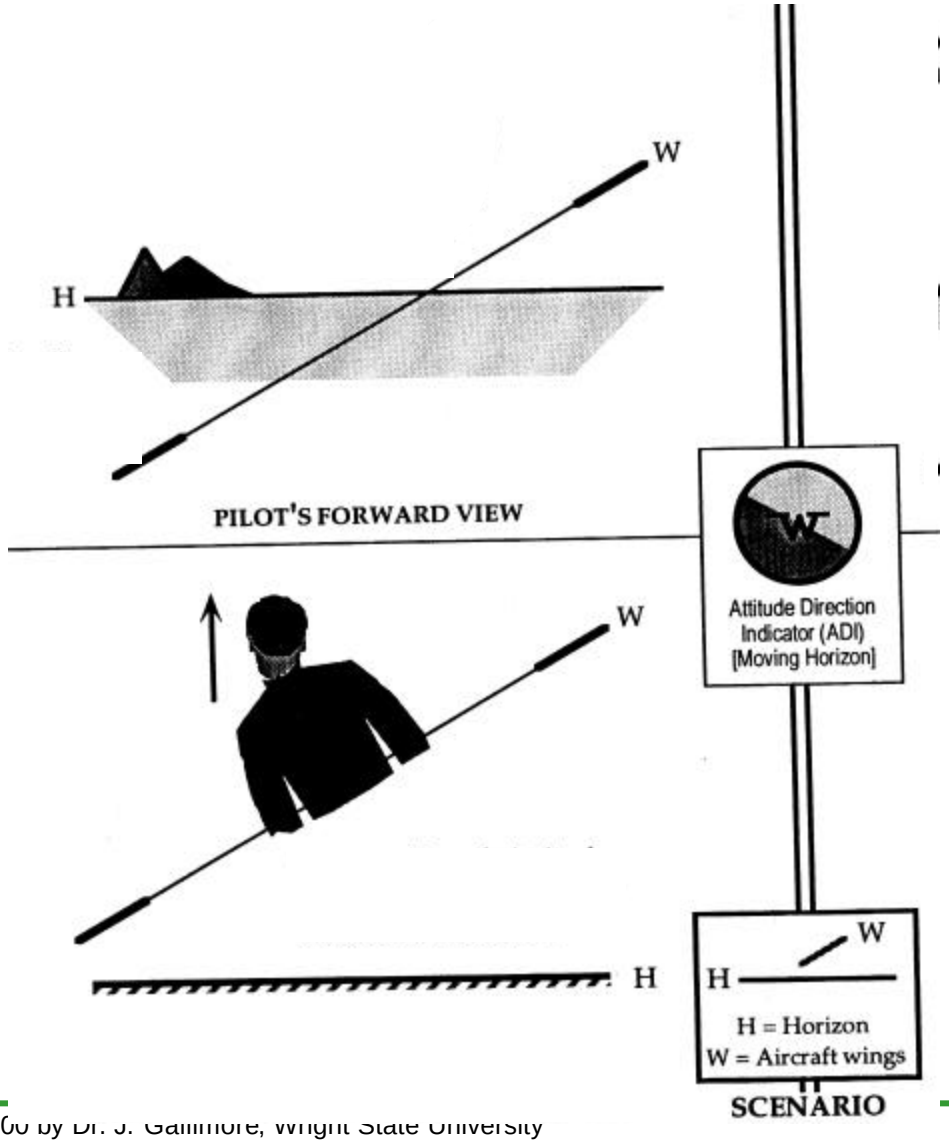


OKCR Studies

Author	Platform	Visual Field Size	Instruments	VMC Task	OCKR Found?	IMC Task	OKCR Found?	UA Task	CRE %	Subs
Patterson (1995)	Fixed aircraft sim	Full dome 180°	HDD AI	X	Yes	X	No	X	65%	16
Smith et al. (1997)	Fixed aircraft sim	Full dome 180°	HDD AI	X	Yes					16
Merryman et al. (1997)	F-15 aircraft	Real world	HDD AI HUD	X	Yes					9
Braithwaite et al (1998)	Moving Heli-copter Sim	Half dome 160° H FOV	HDD AI NVG	X	Yes	X	No	X	25%	20
Gallimore et al. (1999)	Fixed aircraft sim	Full dome 180°	HDD AI	X	Yes	X	No	X	31%	12
Gallimore et al. (2000)	Fixed aircraft sim	Full dome 180°	HDD AII	X	Yes	X	No			26

Patterson's Theory

Pilot's head tilts with the horizon.



Implication

- The horizon is the pilot's primary visual cue and sets their frame of reference.
- When transitions are necessary, frame of reference changes because AI uses an aircraft frame of reference.

Some Research Questions

- What frames of reference are important for a pilot to maintain orientation?
- How do visual frames of reference interact with vestibular and proprioceptive inputs to provide the pilot with an "awareness" of their orientation?
- What contributing cognitive factors affect SO?
- How will HMD attitude symbology affect frames of reference in VMC and IMC?
- How will transitions be impacted?

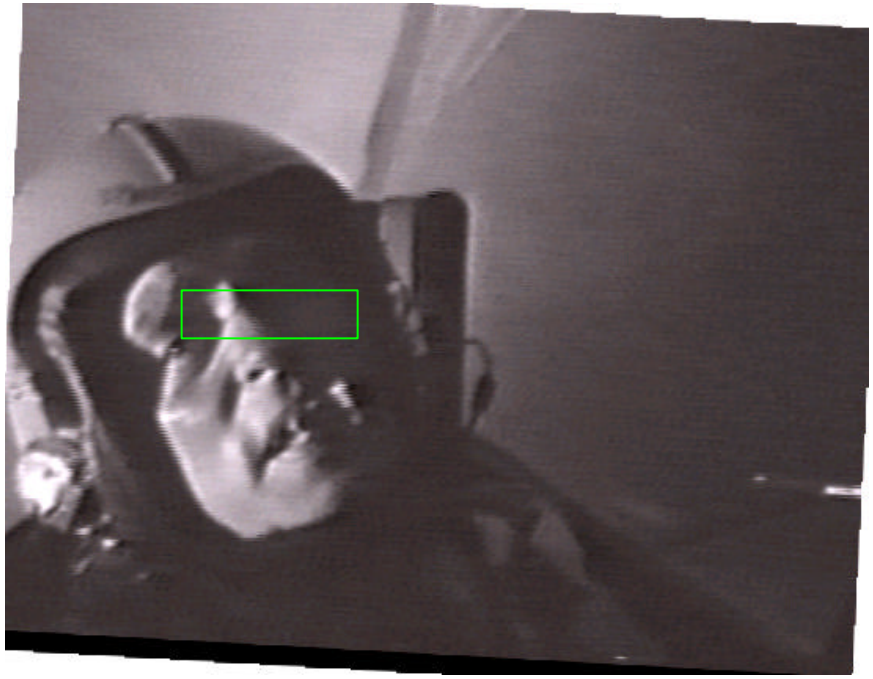
Example

- How does OKCR affect current display technologies?
- Head down Attitude Indicator
  - Reversal errors

Example Cont.

- HUD
  - Head may tilt out of the HUD eye box and pilot may not see a pull up X.

Collimated light from HUD is only visible if the pilots eyes are within a design eye-box: 3” high and 7.5” wide

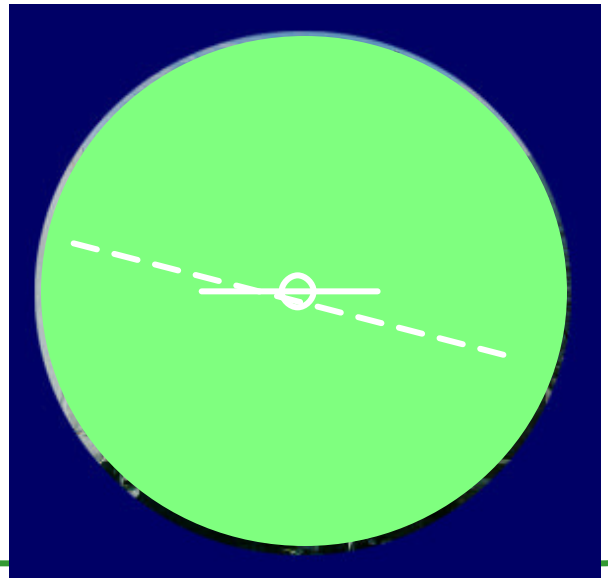


•OKCR changes perspective of geometric symbols projected on the HUD.

F/A-18 aircraft (Blue Angel)
73 degrees of bank (VMC, +Gz Turn).
OKCR Head tilt = 31degrees away from the Gz axis.

Example Cont.

- NVG
  - HUD symbology on the NVG. Head movements are not tracked. As pilot changes head position, display horizon line is no longer conformal to the real horizon.
  - Pilots see HUD information designed for fixed on-axis aircraft viewing regardless of head position. Pilots may not realize they are not flying in the direction they are looking.



Liggett & Gallimore

- Goals and Objectives
  - Provide information for the design of HMD attitude symbology.
  - Test adequacy of Mil-Std HUD symbology presented on the HMD during various tasks.

Hypotheses

- Pilots would tilt in VMC with real-world cues and HMD symbology present (Horizon perceived as fixed).
- Pilots would tilt in IMC with only HMD symbology present. (Horizon symbol ***perceived*** as fixed).
- A sudden transition between different visual cues would show decreased control reversal errors because two reference frames are perceived as fixed.
- Pilot performance would be better with the HMD when frequent transitions between different visual cues were occurring.

Method

- 12 Subjects
  - 100 hrs minimum HUD experience
- Average flight time was 1781 hours
- 7 F-16 Pilots; 2 F-15 Pilots; 2 A-10 Pilots, 1 F-18 Pilot

Flight Simulator

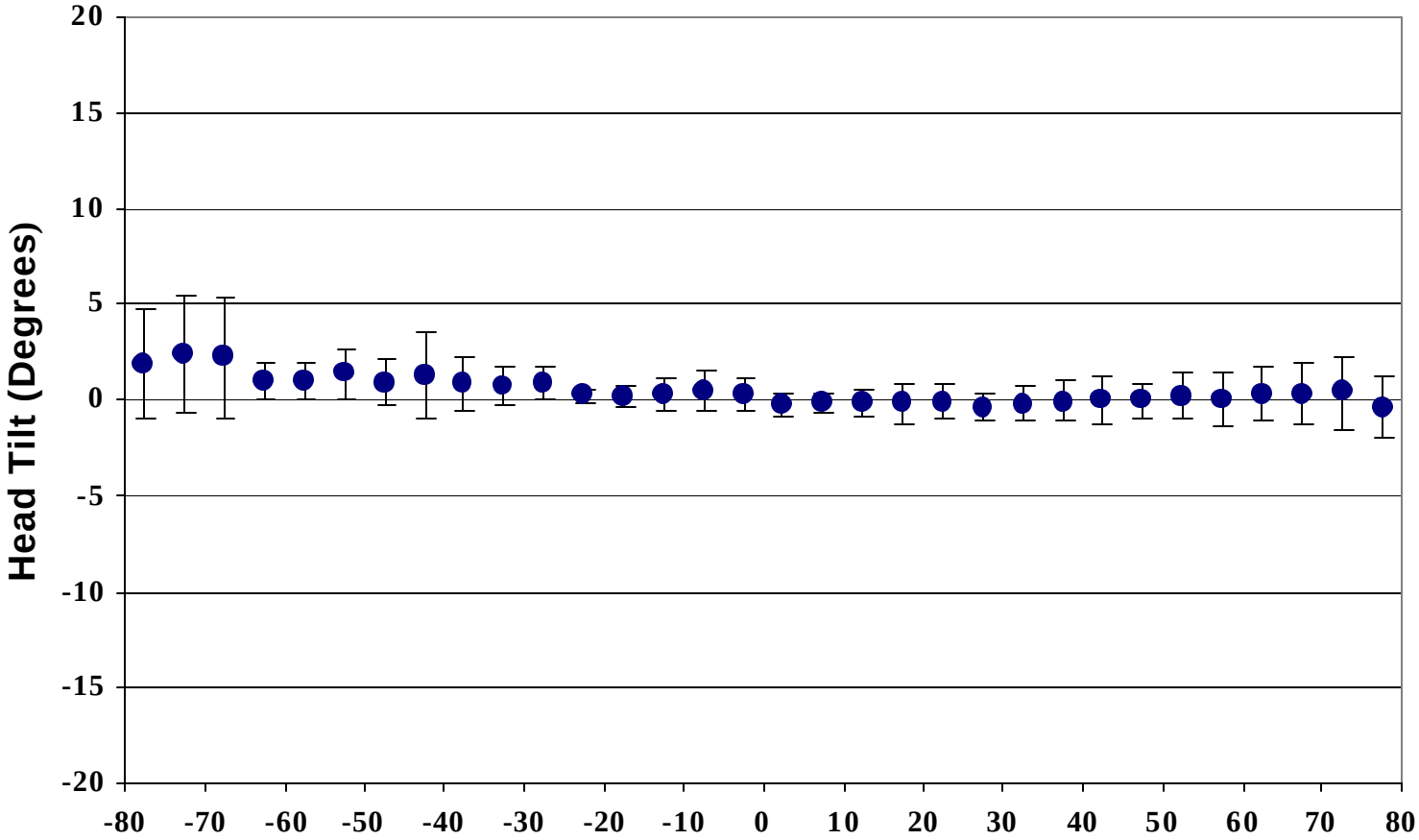
Head Down Displays

Tasks

- I - VMC flight task
  - Pilots were instructed to bank at specific angles, rather than to bank around a waypoint.
- II - IMC flight task
- III - Unusual attitude recovery task
  - Pilots followed lead aircraft into 8 unusual attitudes.
  - Investigated control reversal errors.
- IV - In and out of clouds task
  - Vertical S maneuver with a series of banked rate climbs and descents at a commanded vertical velocity and airspeed.
  - Compared performance with HMD vs. Head down AI.

VMC Task Results

- Subjects did not tilt their heads with any practical significance when performing the VMC task.



Previous OKCR Data

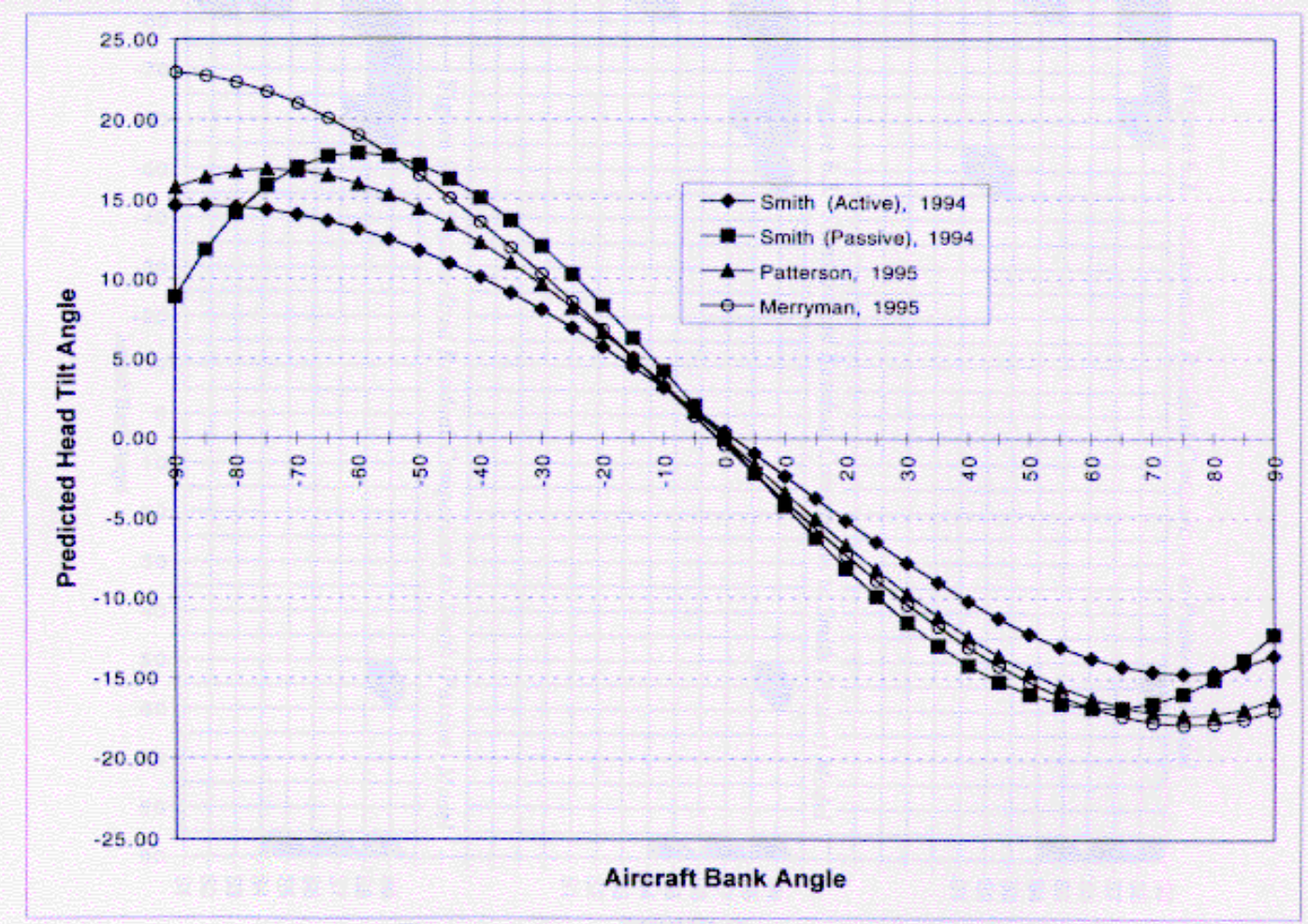
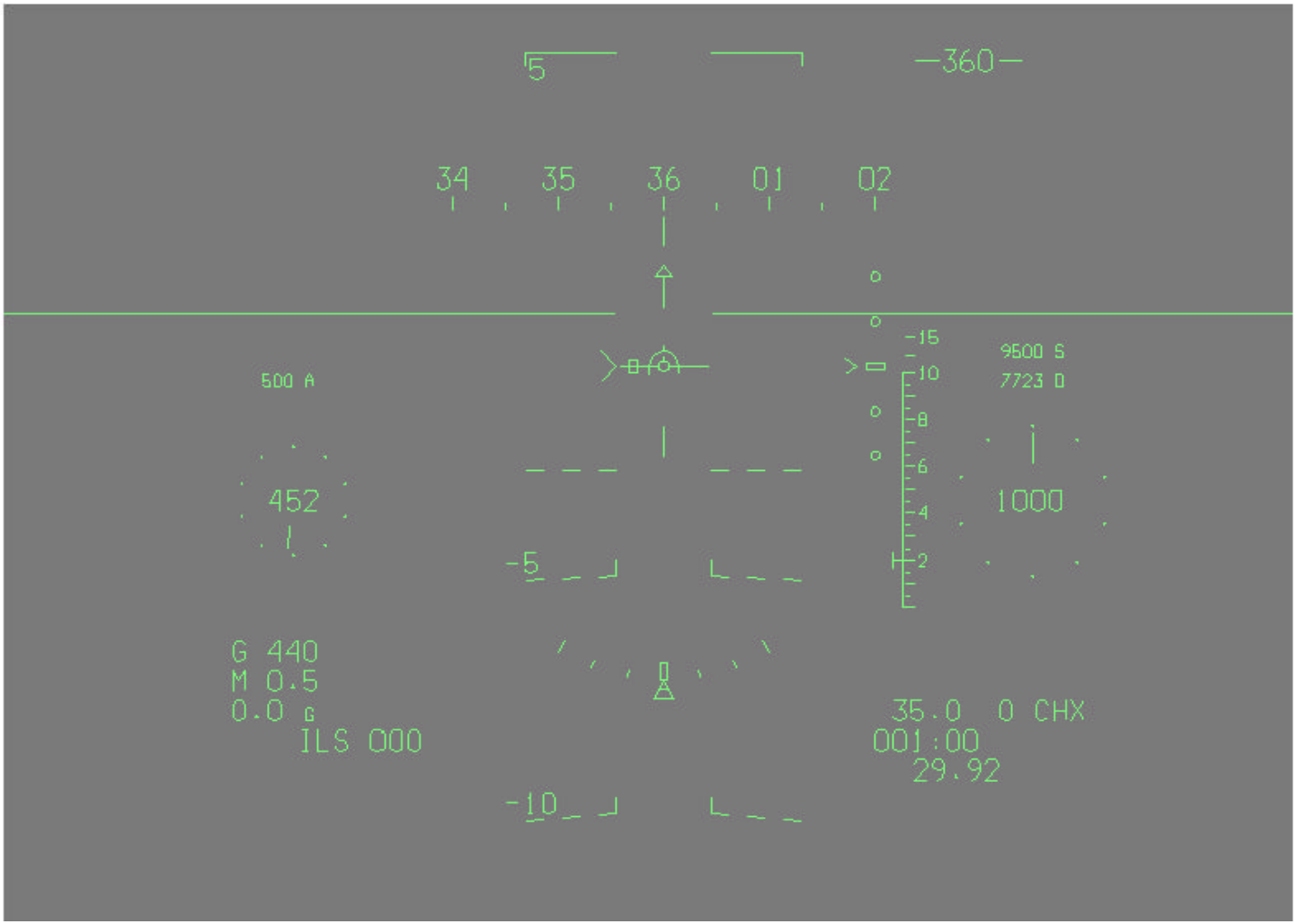


Figure 6.1. *Plot: Four OKCR Response Models*

Results of VMC Task

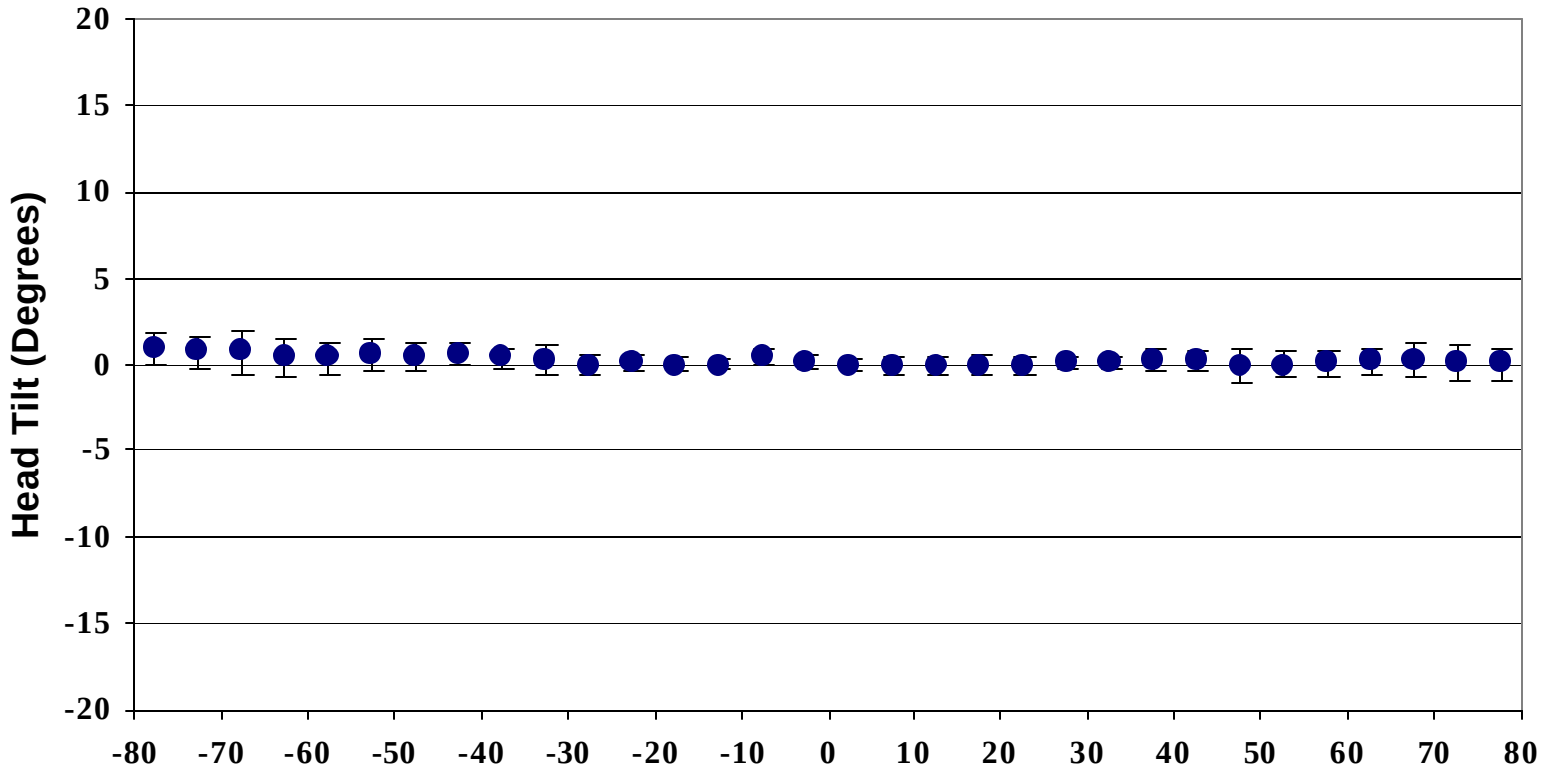
- Previous task specifics
  - Pilots attending to the real-world visual cues.
  - Task was ground-referenced.
  - Primary visual cue for orientation was the true horizon.
  - Natural instinct is the keep the horizon flat on their retinas.
- Current task specifics
  - Pilots attending to the HMD symbology
  - Task was symbology-referenced.
  - Primary visual cue for orientation was the symbology/bank scale.
  - Natural instinct is to keep the symbology fixed in such a way to ease interpretation.

MIL-STD HUD Symbology



IMC Task Results

- Subjects did not tilt their heads with any practical significance when performing the IMC task.



IMC Task Results

- Subjects did not tilt their heads with any practical significance when performing the task. Horizon does not appear to be ***perceived*** as fixed.
- The symbology was the only set of cues to attend to.
- Symbology is aircraft-referenced so majority of symbols are upright at all times.
- Pilots kept head in line with the information they were attending to.

Unusual Attitude Recovery

- CREs as dependent variable
  - Overall CRE rate 28%, similar to previous studies.
  - Magnitude range: 6 degrees to 201 degrees
- A conformal horizon symbol did not reduce CREs.
- Because we know they were not tilting in IMC, they still had to change frames of reference from world to aircraft.

Unusual Attitude Recovery

- Dependent measure: Altitude Change
  - Significant difference
    - CRE group average: 3382 ft MSL
    - No CRE group average: 1810 ft MSL
- Pilots with CREs obviously confused.
- Focusing on pitch and bank information in central part of symbology.
- Fail to scan airspeed and altitude information.

Results In and Out of Clouds Task

- Only vertical velocity deviations showed a statistical difference in terms of display type. HMD errors were lower than head down AI.
- Why did HMD provide better performance in terms of vertical velocity deviations?
  - AI is smaller; precision instrument flying is hard to do with a small head-down instrument
  - Additional visual cues/optical flow when using HMD.


COM1
COM2
NAV
A-A
A-G
LIST
COMM1
7 8 9 ENTER
4 5 6 VOR VHF
1 2 3 TACAN UHF
C 0 000 CRS HF
U123.500
ON
OFF
BIT
BRT
CONT
M 0.41
GS 261
CMD 250
227
29.92
12000 CMD
9587
1.0 G
VV -1454.82
AGL 3740
180
DIST
5675.6
CRS
115
ZZZZ
WP1
UP
67

Summary of Results

- Due to the nature of the tasks, pilots were attending to the symbology only.
- The symbology provided all information for task completion and orientation.
- The visual cue shown to drive the OKCR is the true horizon.
- Pilots were not attending to the horizon during any of the tasks.
- The OKCR was not found.

Implications

- Frame of Reference is determined by pilot's attentional activity.
- The design of symbology can facilitate an optimum relationship.
- Transitions may still be challenging.
  - Examples of possible symbology solutions:
    - Scene-link symbology (Pathway)
    - Provide symbology sets that ease the transition among frames of reference (Malcolm Horizon)

Implications

- It may be possible to reduce spatial disorientation if we
  - channel pilots attention when transitions between two frames of reference are not necessary.
  - facilitate necessary transitions with appropriate symbology sets that will make the transitions as smooth as possible.

Research Issues for HMD Symbology Design

- What spatial sensory reflexes and visual illusions influence pilot's perception of frame of reference?
- Will cognitive capture affect pilots perceptions of frame of reference? Will cognitive capture result in more transitions between symbology and the real world?
- When pilots transition between a perceived stationary horizon (real world cues) to a moving horizon symbol on the HMD, do they perceive the horizon symbol as stationary?
- What type of symbology will help provide the perception of a stationary horizon?

Research Issues for HMD Symbology Design

- If HMD symbology is used for attitude information as well as targeting, how will switching between these tasks affect frame of reference?
- Will pilots have a greater risk of spatial disorientation if they look off-axis more often?
- How will secondary flight cues be affected by use of HMDs?
- What current or new measures should be employed to determine if a pilot is spatially disoriented?

Conclusions

- There is a tendency to want to use existing symbology on HMDs even though it may not be appropriate.
- The HMD provides an opportunity to develop new and unique symbology to reduce pilot SD. (Display symbologies to date have not reduced SD).
- Efforts must be focused on unique solutions.