Review of Visual Clutter and its Effects on Pilot Performance:

New Look at Past Research

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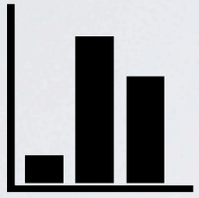
Captain Mark Kelly & astronaut Roberto Vittori on Endeavour, 2011

Outline

Problem

Definition



Past Research

New requirements

Implications for design

Problem

Visual clutter of Primary flight display (PFD) is a design requirement from the Federal Aviation Administration (FAA)

> *Information should be displayed so that clutter is **minimized**.*
>
> (AC 25-11A, 2007)

However, there is conflicting results on it effects on technical flight **performance**

Definition

Numerous definitions from literature

- A cluttered display presents an excessive number or variety of symbols, colors, and other unnecessary information (AC 25-11A)
- Number of objects on the display and to their relevancy according to the cognitive task demands (Yeh et al., 2003)
- Overabundance of useful information (Lohrenz et al., 2009)
- Excess of items, or their representation or organization, leading to a degradation of performance at some task (Rosenholtz et al., 2007)
- Interference between HUD symbols and outside view (Horrey & Wickens, 2004; Yeh et al., 1999)

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Two contributors to clutter

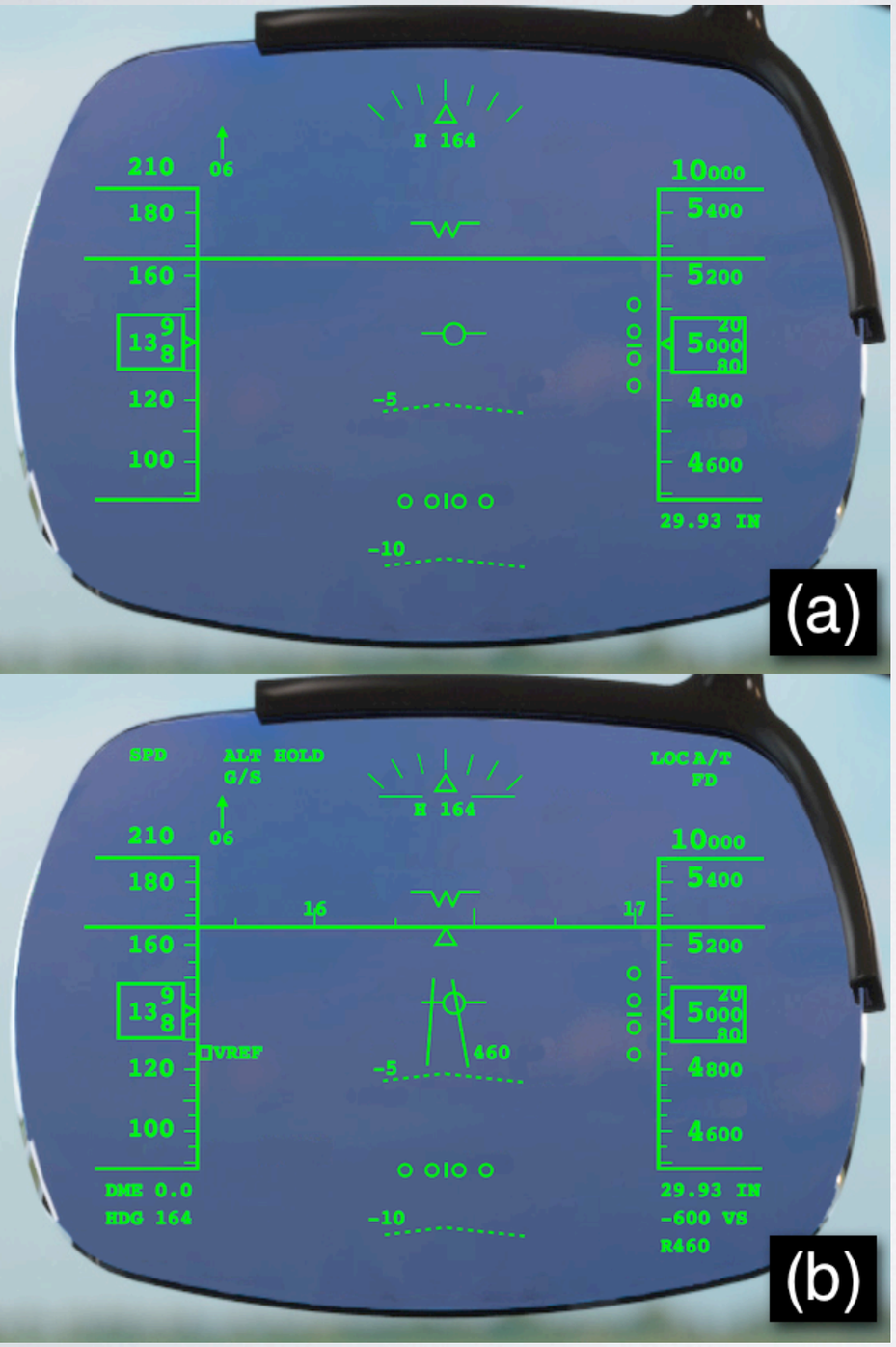
1. **Abundance of symbols.** Stimuli-driven

   Ex. superfluous tick marks, sharp lines, etc...

2. **Irrelevant information.** Goal-driven

   Ex. redundant readouts, mode annunciation, etc...

Definition



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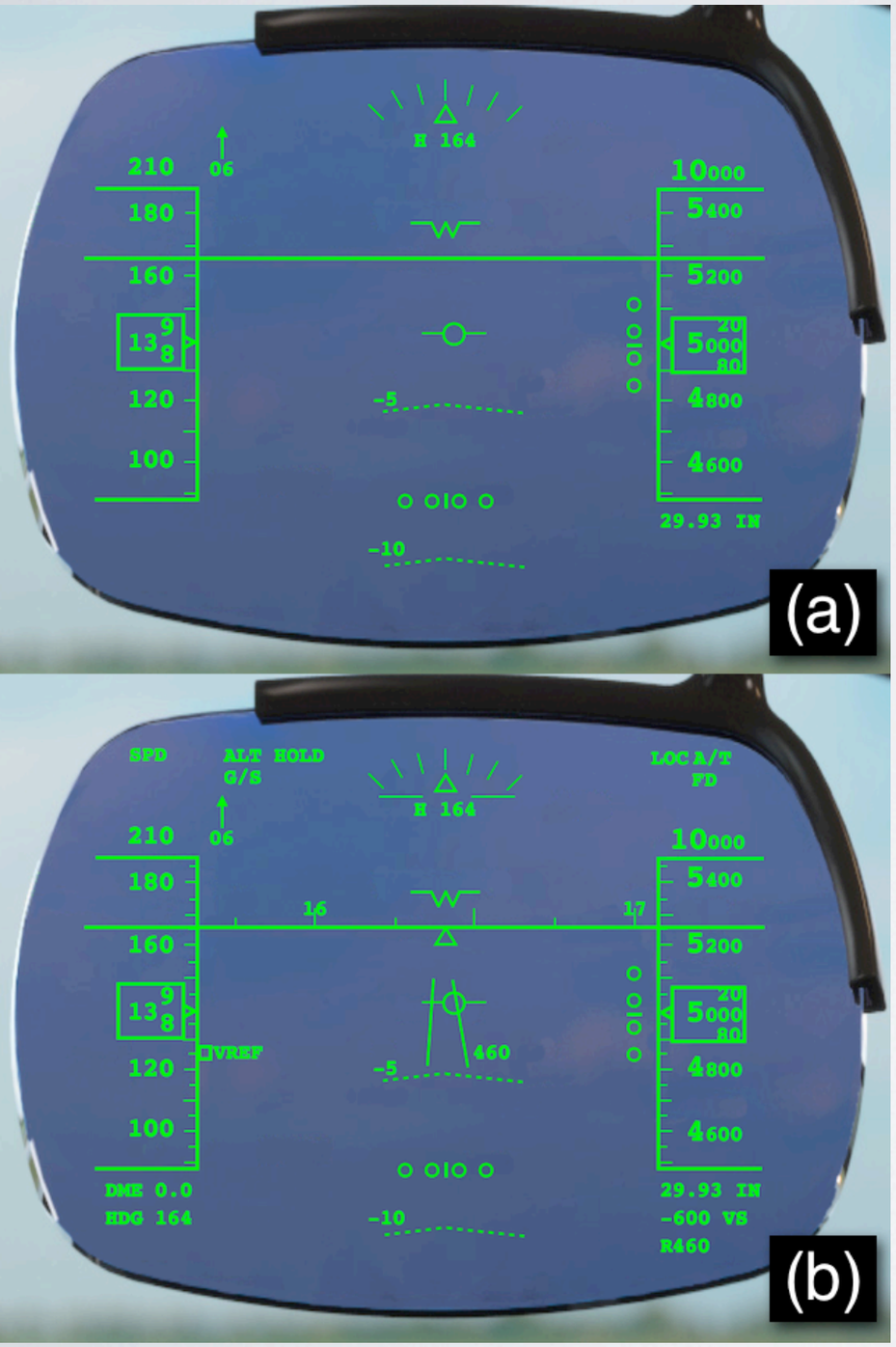

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3. **Context-sensitivity.**

Definition

Context-sensitivity

- The **same message** has radically different meaning depending on the **context.**
(Woods et al., 2001)

- *Ex. Crew Alerting System (CAS)*

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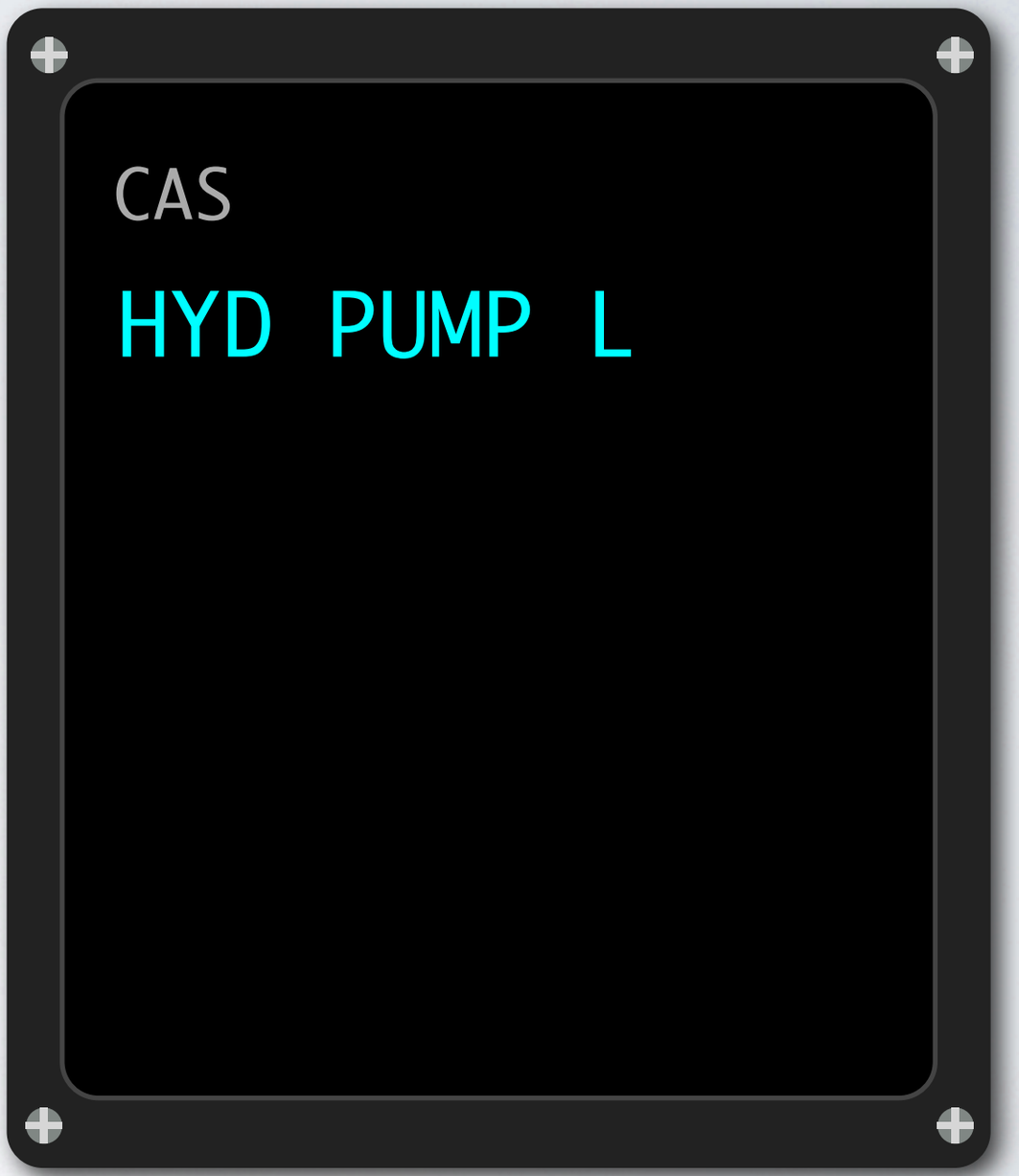

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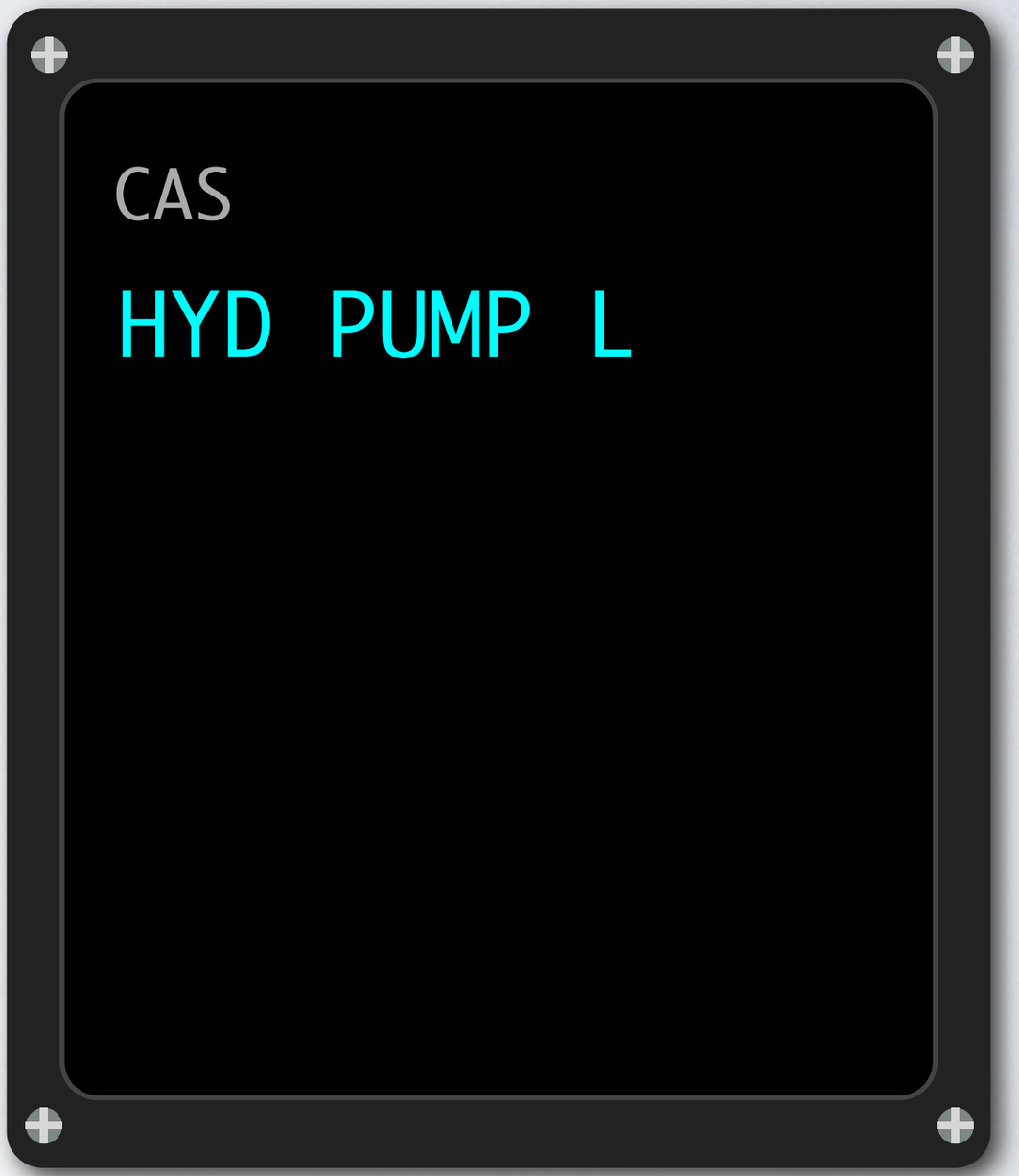

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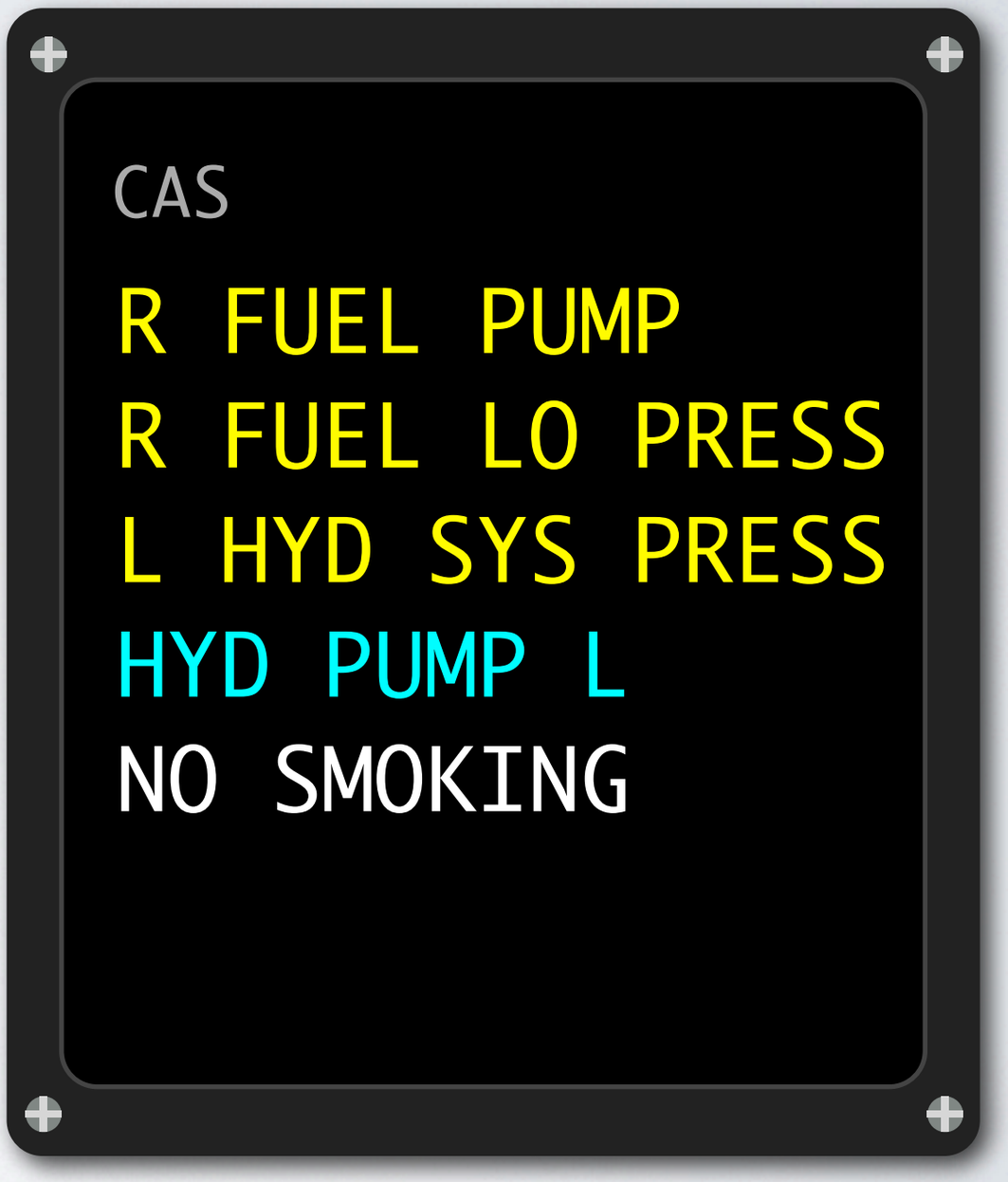
- *Ex. Crew Alerting System (CAS)*
  1. Pump problem
  2. Sensor problem
  3. Troublesome situation...

- Clutter is more than the number of pixels



Clutter Metrics

1) Software

Feature Congest. (Rosenholtz et al., 2007)

C3 (Lohrenz et al., 2009)

Crowding (van den Berg et al., 2009)

2) Questionnaire

Conjoint analysis (McCrobie, 2000)

Clutter rating scale (Kaber et al., 2008)

Visual complexity (Xing, 2007)

Clutter Metrics

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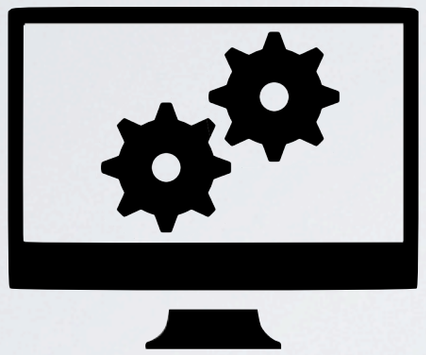


Feature Congest. (Rosenholtz et al., 2007)

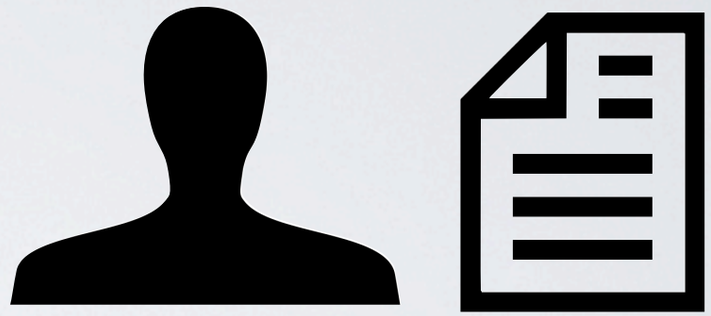
C3 (Lohrenz et al., 2009)

Crowding (van den Berg et al., 2009)

✔ Simple, quick, available

✖ Only for visual abundance

2) Questionnaire



Conjoint analysis (McCrobie, 2000)

Clutter rating scale (Kaber et al., 2008)

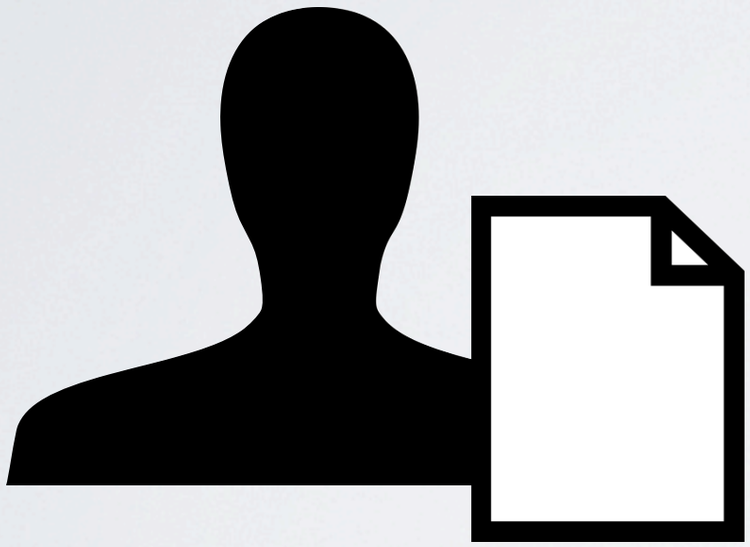
Visual complexity (Xing, 2007)

✔ Abundance + Relevancy

✖ Need subjects, take time

Past Research

Effects on performance



1) Visual search

2) Flight performance

Visual Search

Study	Stimuli	Found	Best performance
Rosenholtz et al., 2007	Weather maps	RT ∝ clutter	Low clutter
Henderson et al., 2009	Outdoor scenes	RT ∝ clutter	Low clutter
Beck et al., 2010	Aeronautical maps	RT ∝ clutter	Low clutter
Palmer et al., 2008	ATC displays	RT ∝ #planes	Low clutter

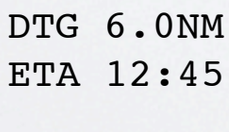
Flight Performance

Study	Displays compared			Best performance
	Low clutter	Med clutter	High clutter	

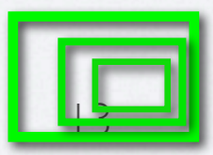
Legend

Flight Director

Readout



Tunnel



Synthetic Vision

Enhanced Vision

Flight Performance

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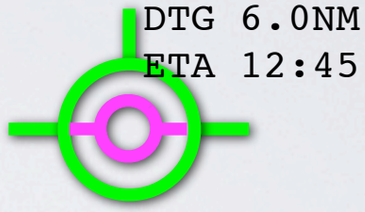
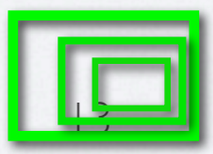
Ververs & Wickens, 1998		-		No effects

Legend

Flight Director 

Readout

DTG 6.0NM
ETA 12:45

Tunnel 

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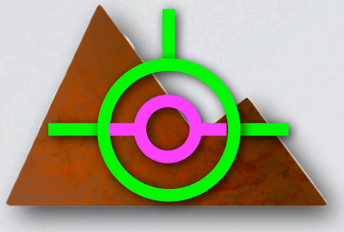
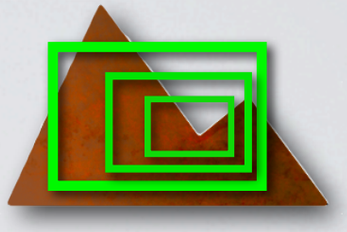
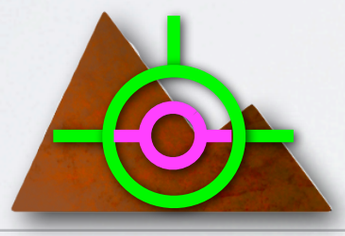
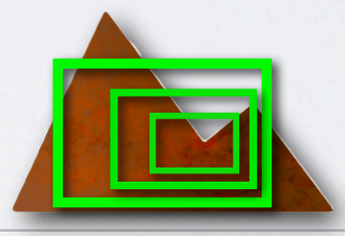
Wickens et al., 2004		-		High clutter
Alexander et al., 2005		-		High clutter

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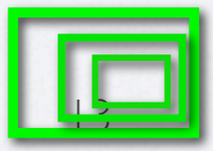
Tunnel 

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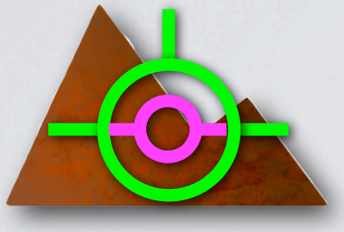
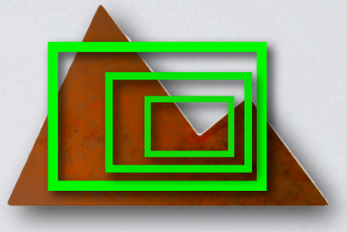
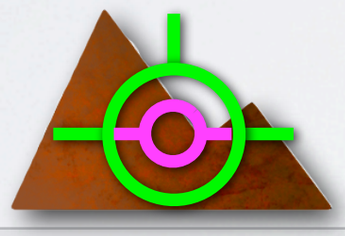
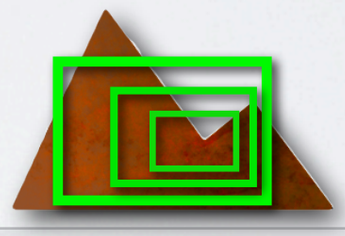
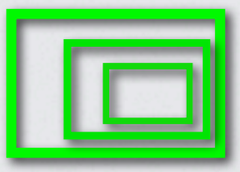
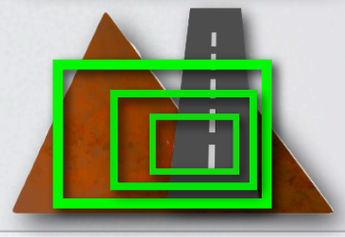
Wickens et al., 2004		-		High clutter
Alexander et al., 2005		-		High clutter
Kim et al., 2011				Medium clutter

Legend

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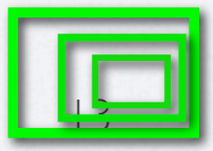
Tunnel 

Synthetic Vision 

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Flight Performance

Why this discrepancy in past results?

Past results suggest that high-clutter displays offer better flight technical performance.

Discrepancy may be explained by the fact that past studies did not manipulate visual clutter in a **similar manner**.

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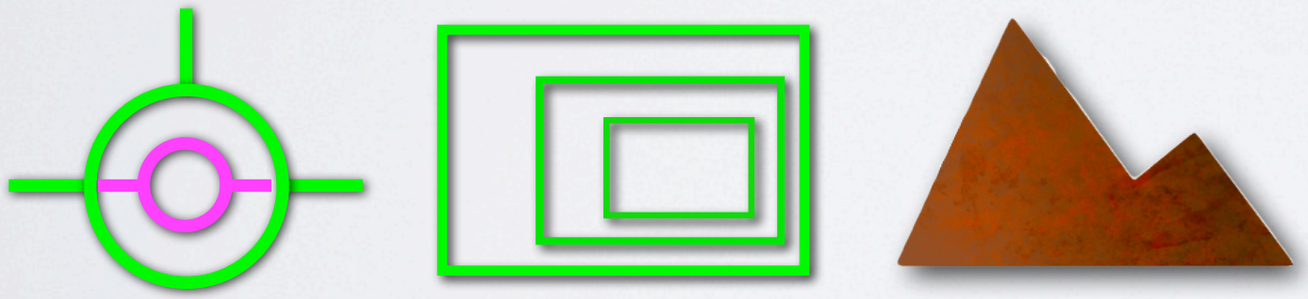

- Different functions
- Different situation awareness

⇒ These factors may have influenced flight performance.

New requirements

Attention should be given to change clutter in a similar manner while leaving other factors unchanged.

To make sure that clutter is changed in a coherent manner, this research propose **three requirements** that all displays must fulfill.

New requirements

New requirements to ensure that the designer changes clutter and not functionality

All displays must provide the same baseline information required for doing the task

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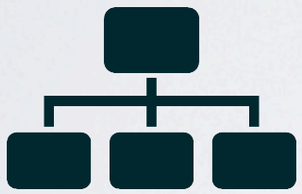


All displays must provide a similar information organization

New requirements

New requirements to ensure that the designer changes clutter and not functionality

All displays must provide the same baseline information required for doing the task

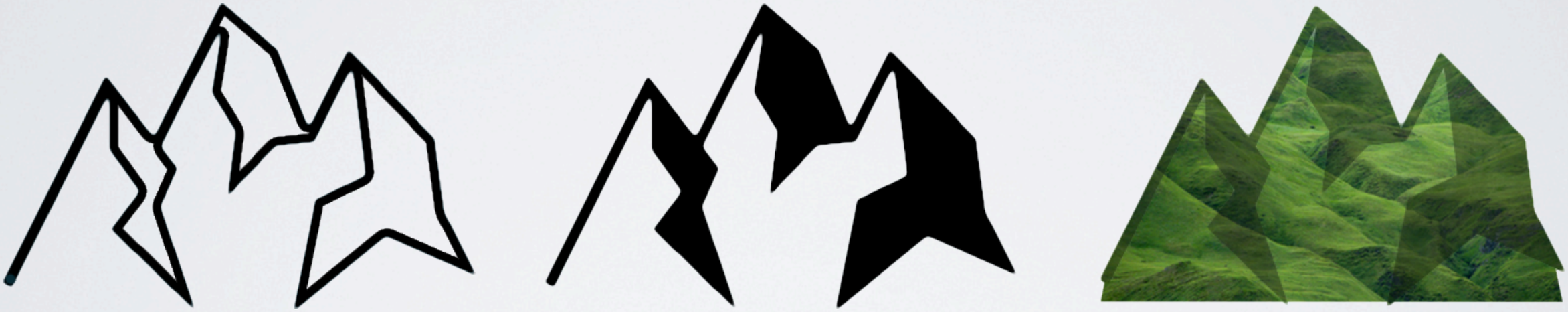
All displays must provide a similar information organization

All displays must provide the same set of functions to the end-user

New requirements

These three requirements restrict the manipulation of visual clutter to that of a similar symbology concept.

Ex: Terrain texture for Synthetic Vision System



a) Fishnet overlay b) Synthetic texture c) Photo-realistic texture

➡ Our model identifies clutter as an **optimization** variable for a single symbology concept, not as an **absolute** value between concepts.

New requirements

Limitation

- *It is difficult to know what information is needed for the task.*

  The requirements do not imply to present **all information** needed for the task.

They require that all tested displays present the **same baseline** information.

Discussion

Demand more attention in future research

Context-dependency — given the system complexity, users will use a display that would be described as cluttered in another task setting.

Task-dependency — Some tasks are more sensitive to clutter than others (ex. focused vs. ambient vision)
(Horrey & Wickens, 2004)

... refine FAA's requirement?

Time-dependency — Most models consider clutter as a static property, but the focus of attention evolves in time.

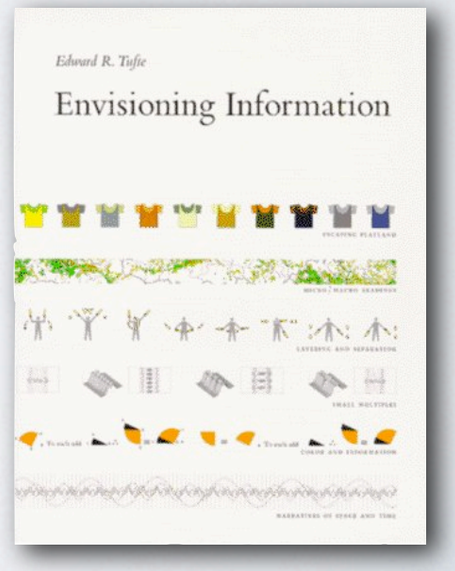
Implications for design

1. Minimize the quantity and density of information displayed.

2. Make task-relevant symbols stand out.
   Ex. increase luminosity (Wickens et al., 2004b), contrasting color (Rosenholtz et al., 2007), dim secondary information (Ververs & Wickens, 1998).

3. Organize the layout of information to depict the relationship between the individual pieces of data.

> *It is not how much information there is, but rather how effectively it is arranged.*
>
> Tufte, 1990

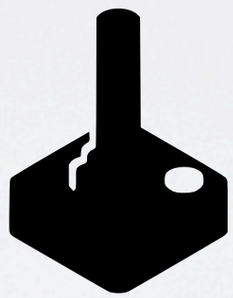


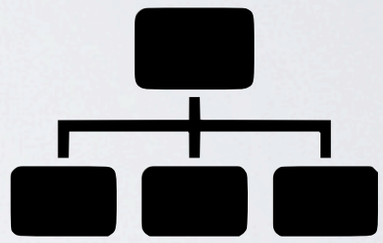
Conclusion

Clutter = Quantity + Relevancy + Context

Mixed results → changed clutter in different manners.

New requirements:





Next step: design displays respecting these requirements and test the effects of clutter in flight simulator (in progress).

For more information...

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